Forest Products Research 1960

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FOREST PRODUCTS RESEARCH 1960

Report of the Forest Products Research Steering Committee with the Report of the Director of Forest Products Research

LONDON
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1961

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CONTENTS

	PAGE
REPORT OF THE FOREST PRODUCTS RESEARCH STEERING COMMITTEE FOR 1960	1
REPORT OF THE DIRECTOR OF FOREST PRODUCTS RESEARCH FOR 1960	2
General	2
Publications and Records	2
Education	3
Visits Abroad	3
Visitors	4
Buildings and Equipment	4
PROGRAMME OF RESEARCH	4
Wood Structure	4
Identification of Timbers	4
Studies in Comparative Anatomy	5
Collection of Timber Specimens	5
Home-grown Timber Investigations	5
The Beta-ray Method of Density Determination	6
Seasoning	6
Kilns and Kiln Seasoning	6
Home-grown Timber Investigations	7
Moisture Content and Specific Gravity of Freshly Felled Conifers	7
Air Drying of Sitka Spruce	7
Colour Changes During the Drying of Beech	9
Wood Bending	9
Solid Bending	9
Laminated Bending	9
Plywood Bending	9
Miscellaneous Tests	9
Timber Mechanics	10
Quality and Properties of Home-grown Softwoods	10
Laminated Construction	11
The Creep of Timber Under Constant Load	12
Woodworking	13
Working Properties of Home-grown Softwoods	13
Comparison of Tool Sharpness	14
Stresses in Circular Saws	15
Woodworking Properties	16
Theory of Cutting	16
Forest Tools	16
Sawmilling Survey	17
Composite Wood	17
Studies of Glues and Gluing	17
Preparation of Veneer	19
Radio-Frequency Heating	19
Wood Preservation	21
Permeability of Sitka Spruce	21
Treatment by Immersion	21
Loss and Movement of Creosote in Wood During Service	23

PAGE

Penetration of Oil- and Water-borne Preservatives into Redwood During Pressure Treatment 23
Distribution of Preservatives in Treated Wood 25
Mycology 27
Culture Collection 27
Natural Durability Tests 27
Wood Preservatives 28
Soft Rot 28
Sap Stain Investigations 29
Miscellaneous Work in Mycology 29
Entomology 30
Ambrosia (Pinhole Borer) and Lymexylid Beetles . . . 30
Lyctus Power-post Beetles 31
House Longhorn Beetle (*Hylotrupes bajulus*) 32
Common Furniture Beetle (*Anobium punctatum*) . . . 32
Death-watch Beetle (*Xestobium rufovillosum*) 32
Parasites 33
Predators 34
Toxicity of Methyl Bromide to Wood-boring Insects . . 34
Laboratory Tests of Wood Preservatives and Insecticides . 34
Gamma Radiation Treatments 34
Sterilization of Insect-infested Wood by Infra Red Heating . 35
General 35
Chemistry 35
Wood Analysis 35
Wood Extractives 36
Wood Polysaccharides 39
Pulp and Paper Research 39
General 40
Physics 40
The Diffusion of Water Vapour in Wood 40
Moisture Relations 41
Effect of Specimen Size on Swelling 42
Correlations Between Vibration Characteristics of Wood . . 43
Density Measurement by Beta-ray Absorption 44
External Relations 45
General Tests 45
Investigations on Home-grown Sitka Spruce 45
General Investigations on Lodgepole Pine 46
Investigations on Lodgepole Pine from Different Seed Provenances 46
Effect of Thinning Grade on the Timber of Scots Pine . . 46
Properties of Individual Growth Rings in European Larch and Japanese Larch 47
Grading of Home-grown Coniferous Logs 47

REFERENCES 47

APPENDICES
I. Staff of the Forest Products Research Laboratory, 31st December, 1960 51
II. List of Publications Issued During 1960 53
III. Reference List of Common Names Cited in the Text . . . 55

INDEX 57

LIST OF ILLUSTRATIONS

PLATES

(Inserted between pages 28 *and* 29)

1. Photomicrographs illustrating some of the crystal features used in Forest Products Research Bulletin No. 46, "Identification of Hardwoods, A Microscope Key".
2. Roofed and unroofed stacks of Sitka spruce used in the air drying experiments at Strachur.
3. A beam loaded to 80 per cent of the ultimate load carried by matched specimens in the standard bending test.
4. Effect of cutting angle on chip formation ($\times 4$).
5. The beam test unit.
6. Apparatus for measuring the electrical constants of wood-glue composites.

7 (a). Sections of Scots pine sapwood blocks impregnated with copper naphthenate in benzene after removal of solvent.

7 (b). Billet trial of creosote as a protectant against blue stain in logs.

8. Eggs of *Paratillus carus* ($\times 30$) in vessels of European oak sapwood.

FIGURES

		PAGE
1.	Effect of roofing on the period required for drying Sitka spruce at Strachur, 1959–1960	8
2.	Deflection-time curve for beam under a constant dead load of 80 per cent of ultimate load carried in standard static bending test.	13
3.	Relationship between the lateral penetration of solvent type preservatives and their physical properties	22
4.	Distribution of copper naphthenate in a $5 \times 2{\cdot}5 \times 1{\cdot}5$ cm block after (a) air drying, (b) vacuum freeze drying.	26
5.	Decay of European spruce sawdust by *Coniophora cerebella*	27
6.	Variation in cellulose content across the stem of Sitka spruce	36
7.	Variation in lignin and pentosan content of Sitka spruce across the stem	37
8.	Variation in 1 per cent caustic soda solubility and alcohol-benzene solubility of Sitka spruce across the stem	38
9.	Nitrogen content variation across the stem in Sitka spruce	38
10.	Variation of initial diffusion coefficient with moisture content	42
11.	Block diagram of beta-ray density equipment.	45

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REPORT OF THE FOREST PRODUCTS RESEARCH STEERING COMMITTEE FOR 1960

To the Council for Scientific and Industrial Research

DURING the year, Mr. H. Douglass retired from the Committee at the conclusion of his period of membership of the Research Council and was succeeded by Professor M. V. Laurie, O.B.E. Mr. Douglass joined the Committee when it was constituted two years ago and we have much appreciated his able services.

In October, Dr. F. Y. Henderson, C.B.E., retired from the Directorship of the Laboratory which he had held since 1945. We would like to pay tribute to Dr. Henderson's devoted service, especially during the difficult period of reconstruction and consolidation after the war, and to welcome Dr. A. C. Copisarow as his successor.

A re-definition of the functions of the Laboratory and its place in the national programme of research was recorded in our report last year, and the period since then has been one of consolidation within these new terms of reference. We now confidently expect the devleopment of much closer relationships between the Laboratory and other organisations concerned with timber. This in turn will aid us in deciding the most effective programme of work for the Laboratory. As a first step we have much appreciated the opportunity at two of our meetings for discussing matters of common interest with Mr. G. B. Crow, the Chairman of the Timber Development Association Research and Development Committee, and with Mr. J. C. Pritchard, Director of the Research and Information Committee of the Furniture Development Council. It is our aim to foster the closest working contacts between the Forest Products Research Laboratory and the Forestry Commission, the Furniture Development Council and the Timber Development Association: for we are certain that only in this way can we ensure the most efficient utilization of available scientific and technical resources in our fields of common interest, and the prevention of unnecessary duplication of effort.

We look forward to increasing collaboration, not only with these bodies but with all others interested in the properties and use of timber, and to the formulation of joint research projects appropriate to the special facilities and long experience available in the Laboratory. We hope that we may be able also to undertake sponsored research or development work for individual firms or groups of firms to help in the solution of technological problems of immediate practical impact. There is no lack of work waiting to be done.

B. K. BLOUNT,

Chairman.

January, 1961.

REPORT OF THE DIRECTOR OF FOREST PRODUCTS RESEARCH FOR 1960

GENERAL

DURING the year under review there has been a considerable increase in the amount of work carried out on home-grown timbers in co-operation with the Forestry Commission. Since forestry in Britain is essentially a long term project, the value of these investigations will become increasingly evident as the forests begin to yield more and more of their crop. Already, however, the survey of the density and moisture content of softwood thinnings has produced valuable data which will assist both in the planning of pulping projects and in the evaluation of the economics of such projects. Research on the seasoning properties of Sitka spruce now promises to show results in an improvement in quality of the timber being milled.

The initial stages of research on pulping have proceeded steadily in spite of delays in obtaining the necessary specialized equipment. A Research Fellow has joined the Laboratory to study the relationships between fibre characteristics of timber and its pulping properties.

The main work of the Station, however, as shown in the following pages, continues to consist of the amassing of a body of specialized knowledge backed by fundamental and applied research, for it is upon this that the more efficient use of timber, in the long term, depends. A not insignificant part of this effort has been made to ensure that, in the interests of the national economy, such knowledge becomes available to those who can best make use of it.

PUBLICATIONS AND RECORDS

New publications issued through H.M. Stationery Office during the year comprise the *Annual Report* for 1959 and *Special Report* No. 14 "Theory of Cutting. Part 1. Experiments in Rectilinear Cutting". The latter report is the first of a series on various experiments designed to provide information that might contribute to the formulation of a theory of cutting. It deals with the cutting forces, when cutting parallel to the grain, at various chip thicknesses and cutting angles. A second edition of *Bulletin* No. 25 "Identification of Hardwoods. A Lens Key", which includes 51 additional species and some minor alterations, was published. *Bulletins* Nos 28 and 34, which give the strength properties of small clear specimens of timber of 2 in. $\times$ 2 in. and 2 cm $\times$ 2 cm cross-sections, respectively, were revised and issued together as *Bulletin* No. 45 "The Strength Properties of Timber", additional data for a number of species in the small size being included. Revisions were also issued of *Leaflets* Nos. 6 "Dry Rot in Buildings. Recognition, Prevention and Cure" and 43 "Prevention of *Lyctus* Attack in Sawn Hardwoods by Use of Contact Insecticides".

In addition to the above, twenty-five papers were published in the scientific and technical press (see Appendix II) and six reports of general interest were prepared.

EDUCATION

Wood Technology Courses. Short courses held in the past for individuals or small groups with specialised requirements have largely been replaced by general Wood Technology courses, for which a fee is charged. Up to twelve persons at a time are accepted and special requirements are catered for on the last day of the course.

The first four courses were based on three days' general instruction with an extra day for specialisation; but it was found that too much compression of the syllabus was necessary and the main part of the course was extended to four days with a fifth day for individual specialisation. It is proposed that a maximum number of six a year shall be held in future.

The syllabus necessarily assumed some knowledge and experience of timber on the part of those attending, but is designed to cover essential ground in the main aspects of wood technology, while the day allocated for individual specialisation allows those more expert or with outstanding problems in a particular aspect to discuss the subject with specialist staff.

Other courses. Ten other training courses to meet individual requirements were held during the year. The courses lasted for periods ranging from 3 days to 9 months and were attended mainly by members of Government departments and institutes.

Six courses of instruction in kiln operation were held and were attended by 59 students.

VISITS ABROAD

During August and September the Assistant Director, Mr. J. Bryan visited North America to attend the Fifth World Forestry Congress which was held at the University of Washington, Seattle. He presented four papers[1–4] on behalf of the Laboratory to the Forest Products Group and participated in a pre-congress tour of California, Oregon and Washington which included visits to various forests, nurseries, sawmills, paper mills, woodworking plants and research centres. After the Congress brief visits were made to the Forest Products Laboratories at Vancouver, Madison and Ottawa.

At the request of the Association of British Plywood Manufacturers the Officer-in-Charge, Composite Wood Section, Mr. R. A. G. Knight, attended meetings of the Fédération Européenne de l'Industrie du Contreplaqué. There were two meetings in Paris concerned with plywood specifications. A further meeting at Karlsruhe dealt with the standardisation of methods for testing bond quality in plywood.

In May and June a senior officer from the Woodworking Section, Mr. K. J. S. Walker, visited Germany, Sweden and Finland, to study sawmilling in those countries. In Germany, visits were paid to a number of mills, in the Black Forest and Hunsruckwald areas, at which the latest developments in German framesawing could be studied. In Sweden and Finland, the Forest Products Research Institutes of the respective countries were visited, and itineraries of visits to sawmills were prepared by these laboratories. At both the Institutes it was possible to see the research work on various woodworking problems, and to discuss it with the staff responsible. The schedules of visits included sawmills of the three main types—bandsaw, circular saw, and framesaw—with emphasis on the latter as being the most common in these countries. The associated equipment for sorting, barking, grading and waste disposal was also studied. It

was possible to visit some of the main manufacturers of sawmill machinery, and in addition to the collection of information on the firms' products, interesting discussions were held with some of their staff on problems of sawmill design, with particular reference to conditions likely to be encountered in the future in Great Britain.

The Officer-in-Charge, Entomology Section, Mr. J. D. Bletchly, was a delegate to the Ninth International Congress of Entomology which was held at Vienna in August. He presented two papers, one to the Wood Preservation Section[5] and the other to the Forest Entomology Section[6]. In connexion with the Congress visits were made to laboratories in Austria, France and Germany.

At the request of the Government of Ghana a senior Officer of the External Relations Section, Mr. A. V. Thomas, was seconded to that country for three months to advise on the setting up of a timber research laboratory.

VISITORS

The number of visitors, excluding those in parties, has risen sharply and was 127 compared to 74 last year. They included foresters, timber merchants, engineers and staff from other Laboratories. The number of parties received was 18, an increase of 2 over the preceding year, and the total number of persons shown round the Laboratory was 373.

Visitors from overseas numbered 76, an increase of 12 over the preceding year, and they represented 27 countries.

Five members of the press visited the Laboratory during the year and were shown the work of the various sections.

Forestry students from the Universities of Aberdeen, Bangor, Edinburgh and Oxford visited the Laboratory and the Imperial College of Science also sent a party of students for one day. In all 104 undergraduates and 16 post-graduate students visited the Laboratory.

BUILDINGS AND EQUIPMENT

A large insectary, mainly for the storage of *Hylotrupes* infested material and incorporating several new constructional features, has been completed.

Work has continued on the modification of the building for the pulp section and further equipment has been obtained.

The radio-frequency generator has been replaced with a more powerful and modern machine.

PROGRAMME OF RESEARCH

WOOD STRUCTURE

IDENTIFICATION OF TIMBERS

The revised version of the Laboratory's microscope key to hardwoods, using the Copeland Chatterson type of perforated card, has been prepared for the printer and should be ready for publication as a Forest Products Research Bulletin[7] early in 1961. Wood anatomists who have been using the original key devised by Clarke in 1936 [8, 9] should note that the revised version embodies

certain alterations to the list of features used in the identification process. Thus the classification of ray tissue is based on the system of Kribs[10] and use has been made of Chattaway's[11] findings on the diagnostic value of crystals in woody tissues to subdivide the relevant features. Some crystal forms are illustrated in Plate 1. These changes have meant designing a new card, so the cards originally issued are not suitable for use with the new key.

STUDIES IN COMPARATIVE ANATOMY

Work under this head has been confined to studies connected with the revision of the microscope key to hardwoods, referred to above, and to a few species outstanding from the Laboratory's programme of investigations on timbers from overseas, namely, nkoba and mushebeya from Uganda, white seraya and a light red seraya from North Borneo, and *Khaya grandifoliola* from Nigeria.

COLLECTION OF TIMBER SPECIMENS

Notable additions to the reference collection during the year included collections of local timbers all correlated with herbarium material obtained by courtesy of the Brunei and Northern Rhodesia Forest Departments; also an important collection of woods grown in Yugoslavia, received from the Forestry Faculty of the University of Zagreb, a small collection of Vietnam timbers from the Technische Hochschule, Dresden, and microscope slides of rare conifers from the University of Szeged, Hungary, all under exchange arrangements. The exhibit collections have been kept up to date and have been in constant use in connexion with courses of instruction and for demonstrating to visitors.

HOME-GROWN TIMBER INVESTIGATIONS

Sitka spruce. As part of the first phase of the systematic investigation of Sitka spruce, studies of the variation in wood structure in trees from a wide range of sites have been proceeding. The primary object of this extensive investigation is to determine the effect of site factors on the properties of the timber. Fibre dimensions are of some importance in determining the quality of the wood for paper and other pulp products. The results of investigations on material drawn from six broad geographical regions of the United Kingdom indicate some relationship between fibre length and both geographical region and Site Quality Class, and further investigations will be necessary to elucidate the relationship.

Two natural defects that influence the quality of softwood are spiral grain and compression wood, and both are of common occurrence in Sitka spruce. Present indications are that the incidence of these defects is not closely related to geographical region or Site Quality Class and the results are being analysed to investigate the significance of local growth conditions and sylvicultural factors in this connexion.

A start has been made on an intensive study of the pattern of variation in structure within the tree. This is designed to provide the knowledge required for investigations based on systematic sampling methods.

The procedure for estimating the timber quality of so-called plus trees by non-destructive methods of sampling has been worked out in co-operation with the Forestry Commission. To avoid permanent injury to the trees the wood samples extracted from the main stem must be small in size and few in number. It has been found convenient to take samples in the form of cylindrical cores,

11 mm in diameter, using an increment borer. During the year trial samples have been provided by the Forestry Commission and a standard procedure for boring the trees and examining the sample cores has been worked out. It involves observations on density, including the variation from spring wood to summer wood across the growth rings, measurements of fibres and the inclination of the grain, and chemical analyses (see p. 35). At a later stage wood samples taken from the progeny of the plus trees will be examined and compared with the wood of the parent trees. This will show to what extent the characteristics in question are inherited and should ultimately enable the quality of Sitka spruce to be improved by breeding from trees with the more desirable type of timber. The main objectives for improving the timber of this particular species are as follows:

(1) To increase the density of the wood, particularly in the juvenile core and preferably by breeding for denser spring wood so as to reduce the contrast between spring wood and summer wood to give a more even texture.
(2) To increase the length of the fibres, particularly in the first-formed rings of the juvenile core.
(3) To increase the percentage of cellulose and reduce the percentage of lignin.
(4) To reduce the length of the juvenile period and hence the diameter of the core of inferior juvenile wood.
(5) To reduce the incidence of compression wood and severe spiral grain or other forms of irregular grain.

Lodgepole pine. This species has possibilities for planting on a fairly large scale in this country and a trial consignment of logs from a 28 year old plantation at Blessington, near Dublin, has been supplied to the Laboratory for a general assessment of the timber. This preliminary investigation is nearly completed. The structure of the wood is typically intermediate between that of the soft pines, e.g. yellow pine, and the hard pines, such as Scots pine. This gives the timber a relatively uniform texture which, combined with its moderate density, suggests that it may be a useful addition to the number of exotic softwoods already being grown for timber in this country.

THE BETA-RAY METHOD OF DENSITY DETERMINATION

As previously reported, the relative absorption of beta-rays has been used successfully to measure the density of wood[12]. During the year further work has been carried out in co-operation with the D.S.I.R. Radio-Isotope Applications Unit at Harwell, to improve the method of recording the variation across a growth ring, in connexion with the current series of investigations on home-grown softwoods. The wood specimen in the form of a strip 8 mm thick has been replaced by a microtome section 100 microns thick and this has involved the use of carbon-14 as the radio-active source instead of strontium-90. An account of this work is given on page 44.

SEASONING

KILNS AND KILN SEASONING

The large kilns were used for seasoning consignments of mansonia, afrormosia, beech, niangon, walnut, *Khaya grandifoliola* and abura. The beech was in the form of dimensioned stock to be used for furniture making and one of the two

loads seasoned was deliberately overdried and then rewetted in the kiln to the required final moisture content. By doing this it was possible to measure the reduction in all forms of distortion brought about as a consequence of the rewetting. The afrormosia was 3 in. and 4 in. material intended for pattern making and this dried with little degrade and very quickly to a uniform moisture content.

In the smaller kilns, loads of ironwood brushboards were seasoned to determine the optimum schedule for drying these down to a low moisture content for export to the North American market. The material dried very slowly and was very liable to surface checking, but a successful schedule employing relatively high humidity conditions was developed.

HOME-GROWN TIMBER INVESTIGATIONS

The seasoning properties of home-grown Sitka spruce, as supplied from eighteen sites under the terms of the programme of work that is being carried out in co-operation with the Forestry Commission, have now been investigated. The results obtained have been analysed and comparisons made. There was no difference of statistical significance between the final quality of the dried material from the six regions sampled. There was, however, some difference between the material from the different sites and also from different trees.

Two series of tests were carried out on lodgepole pine, the first to determine the optimum drying schedule for the species and the second to compare the seasoning properties of this timber as derived from nine different provenances. Thirteen test runs have been carried out on this species. The species was found to be very tolerant of severe drying conditions and showed very little tendency to check or split. Distortion also was moderate apart from longitudinal curvature or "bowing". More longitudinal shrinkage was observed to occur near the heart than near the bark and this difference was responsible for many of the boards curving longitudinally towards the heart.

Test runs are in progress to compare the seasoning properties of Scots pine from trees which received different thinning treatments during growth. The series of tests to determine the seasoning properties of home-grown Turkey oak have been concluded. This species was found to be an unusually refractory one, and the timber tended to shrink an excessive amount in whatever manner it was dried. All forms of distortion were severe, particularly cupping, and the pronounced tendency for the wood to split required such high humidity conditions that the drying period was very lengthy and uneconomical. Supplementary tests were carried out by air-seasoning material, some of which was initially impregnated with hygroscopic salts, but with little success.

MOISTURE CONTENT AND SPECIFIC GRAVITY OF FRESHLY FELLED CONIFERS

This investigation which has involved the testing of over twenty-two thousand samples has now been completed. Supplementary tests made on Sitka spruce from two sites and on five separate occasions showed that the moisture content fluctuated according to the time of measurement and this will need to be taken into account when the results of the major scheme are analysed.

AIR DRYING OF SITKA SPRUCE

Experiments on the air seasoning of Sitka spruce which were started last year at Culloden and Strachur have been continued (see The Annual Report for

1959, p. 7). In October 1959, piles of 4 in. $\times$ 2 in. and 4 in. $\times$ 1 in. material were stacked in the open at Strachur and provided with roofs of corrugated iron. Alongside these, a similar pile of 4 in. $\times$ 2 in. material was erected but was not provided with any form of roof (see Plate 2). The rates of drying which were recorded for these three stacks are shown in Fig. 1. It will be observed that

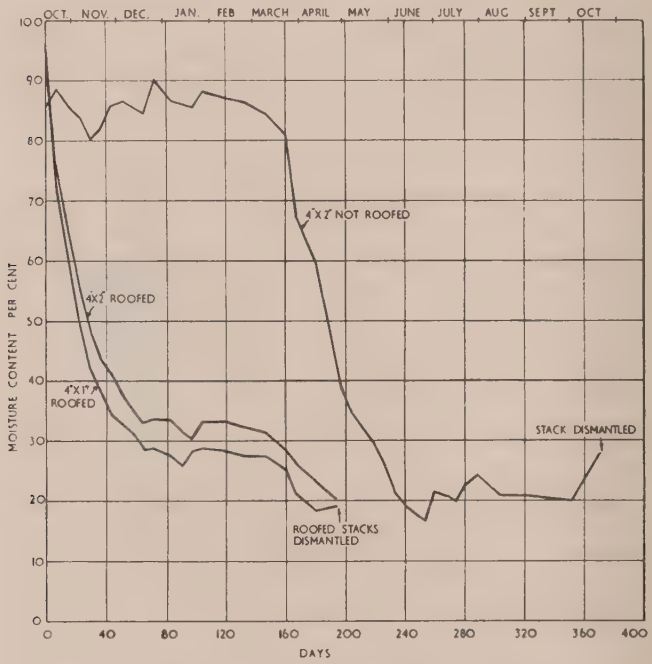


Fig. 1. Effect of roofing on the period required for drying Sitka spruce at Strachur, 1959–1960

virtually no drying occurred in the unroofed stack of timber until towards the end of March. In the roofed stacks on the other hand fairly rapid drying took place in both October and November despite the fact that there was heavy rainfall during these months. Further very heavy rainfall was recorded in December; nevertheless, before the turn of the year, less than three months after the timber was put out for drying, the moisture content was in the region of 30 per cent. It was not, however, until March that any appreciable further drying took place, but by the end of April the moisture content was down to 20 per cent. The unroofed material had by then reached a moisture content of about 40 per cent but was then drying fairly rapidly, so that six weeks later it also was at a moisture content of 20 per cent.

New stacks of 2-in. material with and without roofs were erected in April 1960 both at Culloden and Strachur. The influence of a roof on the rate of drying was found to be far less marked during the spring and summer months than during autumn and winter, but a roof had the effect of lessening the intensity of moisture content fluctuations in the material once it had become relatively dry.

COLOUR CHANGES DURING THE DRYING OF BEECH

For some purposes it is desirable that the natural light colour of beech should be retained in the finished article. Very often, however, appreciable darkening in colour occurs during the drying process, particularly in kiln-drying. Some preliminary tests have been made, the results of which suggest that one way of reducing this discolouration may be to dry the surfaces of the timber very soon after it is cut from the log. There is an obvious risk that quick surface drying may cause surface checking to develop, but a first attempt at modifying the normal kiln-drying schedule by using comparatively low humidities for a short period at the commencement of a run gave promising results, and further work on these lines is intended.

WOOD BENDING

SOLID BENDING

Standard tests have been carried out to determine the bending properties of *Khaya grandifoliola*, white seraya and a species of light red seraya.

Supplementary large scale tests have been carried out to investigate the bending potentialities of hornbeam. Earlier work had indicated that bends of large radii of curvature could be set more accurately to shape by radio-frequency heating than by the more orthodox drying in a heated chamber. Further tests have shown however that bends set by the radio-frequency process have a tendency to lose shape during conditioning and storage.

It has long been known that bending woods such as beech, if steamed and compressed longitudinally, can be bent with comparative ease in the cold state; such timber has sometimes been referred to as "flexible wood". Tests have been made to examine the flexibility of beech so compressed by bending thin samples at 12 per cent moisture content and in the cold state around unheated jigs. Results have shown conclusively that the greater the initial compression, the smaller the breaking radius. The relationship between breaking radius and initial compressive strain is approximately linear. Further tests are in hand to investigate the effects of moisture content and other factors on the properties of compressed wood.

LAMINATED BENDING

Standard tests have been carried out to determine the breaking radius of various species and thicknesses of laminae. The species tested have included five hardwoods and one home-grown softwood.

PLYWOOD BENDING

The large scale investigation on the bending and setting of birch plywood has been continued. Data have been obtained on the influence of the ply thickness, the direction of the grain of the face veneers and the moisture content on the breaking radius of specimens when bent in the cold state.

MISCELLANEOUS TESTS

At a request of a manufacturer of sports goods, one hundred and fifty "Indian shape" ash hockey stick bends have been made by the method which was developed at the Laboratory and described in the 1957 Annual Report p. 12. These have been supplied to the firm for trial purposes.

TIMBER MECHANICS

QUALITY AND PROPERTIES OF HOME-GROWN SOFTWOODS

The experimental work to investigate the strength and specific gravity of Sitka spruce grown in Great Britain has been completed during the year under review, and the results have been analysed.

The Forestry Commission divide the British Isles into eleven geographical regions corresponding to the Meteorological Office "Districts". They also classify each stand into one of five groups, known as Site Quality Classes, according to the height to which trees of a given species grow in a certain time. These Quality Classes and the eleven regions formed the basis of the sampling for the investigation. Ten trees from three sites each of a different Quality Class, were sampled from each of six different regions. Measurements of compressive strength, impact bending strength, specific gravity and specific strength (compressive strength/specific gravity) were made.

The main objects of the investigation were to study the variations in the strength and specific gravity of the home-grown Sitka spruce and to see if these properties were related to the region of growth or were associated with any site factors. In addition the relationship between girth and the various properties was to be examined.

The analysis of variance of the results as a whole gave the same general conclusion for all properties. There was no significant difference between the six regions sampled but significant differences between the sites within regions and between the trees within a site were found. This indicates that differences in quality as measured by specific gravity and strength tend to arise more from individual site factors rather than from differences in climatic conditions.

With all properties there were no significant differences between Quality Classes as a whole. Although there were no significant differences when considering the Quality Classes as five separate classes several important differences did emerge when they were combined. Thus Quality Classes I and II together were significantly lower in impact strength and specific gravity than the combined classes III, IV and V. There were no marked differences between combinations of classes for compressive strength, but the specific strength of Quality Classes I, II and III together was appreciably higher than that for the combined Quality Classes IV and V. The specific strengths indicate that the higher specific gravity of the combined Quality Classes IV and V was not accompanied by a corresponding increase in strength. If a reasonably high specific gravity accompanied by a correspondingly high strength is required for a fairly fast growing tree, this will be best achieved by growing Quality Class III timber.

Generally the girth of the tree gave a significant correlation with the various properties measured but the relationships were not definite enough to be of any value in predicting their values. A tendency for the top of the tree to be less dense and less strong than the lower portion was noted, but it was not sufficiently great to be of any real importance.

Lodgepole pine is being used in afforestation to an increasing extent. The species is endemic to N.W. America and was only recently introduced into this country. In consequence it cannot be assumed that the quality of the home-grown timber will compare favourably with that produced in N. America.

Lodgepole pine seed is imported from a number of places in N.W. America and it is not known if the origin of the seed has any effect on the timber

properties. In particular no information is available to indicate the most suitable seed for use in this country, and an investigation has been commenced to compare the properties of the timber produced from nine different seed provenances of the species. The provenances covered ranged from California to Alaska.

The results obtained so far indicate that two provenances from Vancouver Island are appreciably stronger and denser than the others. Unfortunately these two provenances were not grown on the same site as the other seven and consequently the differences observed could be due to site effects. In view of the relatively large differences in strength, namely 15 to 30 per cent, it would appear that further sampling of the two Vancouver provenances should be made to allow a better comparison of the quality of the timber obtained from the two sources. Of the other seven provenances, that from East of Kamloops in British Columbia was the strongest.

As reported in last year's Annual Report (p. 14) advice was given to the Forestry Commission on the design of an experimental bungalow to be built from home-grown softwoods. During the year assistance has been given in the construction of the bungalow and in the design and construction of an exhibit for the Royal Highland Show which illustrated the type of construction used in the bungalow.

LAMINATED CONSTRUCTION

Working Stresses. The investigation to determine working stress values for laminated timber described in the 1959 Annual Report (pp. 10–13) has been completed and a full report is now in the press[13].

A somewhat different procedure is followed when deriving working stresses for laminated timber than for sawn timber. Basic stresses are first determined. Rules for stress-grading are then formulated and the strength ratios for the grades and for combinations of them are derived for the number of laminae that will be used to make up the member. In the report mentioned above grading rules for laminated timber are suggested. Relationships between strength ratio and number of laminae have been determined from a study of the incidence and influence of knots. These results are presented in a simple graphical form so that working stresses for a particular construction can be derived by multiplying the basic stresses for the species by the appropriate strength ratio read directly from the graphs. So that advantage may be taken of the increased strength that results when wood is dried, basic stress values for a number of species for two conditions of exposure are included in the report. The conditions correspond to damp or external exposures and to dry or internal exposures where the moisture content of wood will not generally exceed 18 per cent.

The results of the investigation also show that for samples of imported Douglas fir and home-grown Scots pine and larch common factors may be used to determine the working stress values without incurring errors of any practical importance. Since these species contained a wide variety of size and type of knot, it may be that these common relationships are applicable to softwoods generally. The extension of the data to sections other than those on which the actual tests were made will depend upon a similarity in distribution of knot ratios in material of different widths. However, since the material was graded and since relatively narrow laminae were used throughout the investigation, any differences that do occur will tend to give higher working stresses than those derived from the common relationships. It is intended to continue the study of knot incidence so that direct comparisons of the distributions may be made.

In the investigation samples of advanced thinnings of home-grown Sitka spruce were included, and it was found that although the knots in this material were of relatively greater size than for the mature woods they did not have as great an effect on the ultimate strength properties. The incidence of knots also was too great to allow knot-free laminated specimens of 3 in. × 6 in. cross-section to be fabricated for laboratory tests. It was therefore not possible to determine directly the ultimate strength in bending and compression of clear laminated material. Values for these properties were however derived by extrapolation from the regression equations of strength on knot ratio, and these were found to be much lower than the averages for clear, sawn Sitka spruce. The presence of juvenile wood which is distributed in laminated members throughout the cross-section suggests that such differences are real and it is obviously desirable before working stresses for laminated members are determined to modify the basic stress values. From limited tests modification factors of 0·75 for bending strength and 0·85 for compression strength were suggested for Sitka spruce thinnings material. Beyond demonstrating that there is likely to be a difference in the basic stress values the data were not extensive enough for any general conclusions to be drawn, and further investigation is desirable if thinnings material of other species is to be considered for laminated construction.

Influence of Curvature. One important advantage associated with laminated construction is that it enables curved structural members to be produced in timber. Stresses are induced in the individual laminae during fabrication, and these may affect the strength properties of a finished member. A series of tests were made on curved laminated beams in larch, Sitka spruce and redwood to investigate this point[14]. The results indicated that while modulus of elasticity was unaffected by the initial bending of the laminae the bending strength was significantly reduced as the severity of the curvature was increased. When the ratio of the thickness of the laminae to the radius of curvature was smaller than 0·008 the reduction or loss in strength was on average greater than that suggested by the limited data previously available. From the average results the loss in strength associated with increasing curvature ratios was found to conform to a simple linear equation. When deriving working stress values for curved laminated members the basic stress in bending for the species should be modified by a factor which may be obtained from the expression $[1 - 15t/R]$ where t is the lamina thickness and R the radius of curvature in the same units.

General. A paper dealing with the investigations on the properties of laminated timber was prepared and presented at the Fifth World Forestry Congress[4]. At the request of the Forestry Commission a survey was made of the possibilities of using laminated timber for bridge constructions which included a design analysis and the calculation of required sections. It was concluded that in Britain laminated timber was likely to be more expensive than other materials for road bridges even of short span, but that for pedestrian traffic alone it might be used.

THE CREEP OF TIMBER UNDER CONSTANT LOAD

The constant load tests on small beams of noble fir have continued. These tests are part of the investigation on creep in beams which was commenced in 1958 (see the 1958 Annual Report, p. 12). The beams, 2 cm × 3 cm in cross-section, are loaded over a span of 60 cm at the third points with dead loads

corresponding to various percentages of the ultimate load carried by matched specimens when tested in static bending in accordance with standard procedure. These percentages ranged from 90 to 30 per cent. All the beams tested so far at load levels of 60 per cent and over of their ultimate bending strengths developed compression failures near or between the load points during the application of the load. Plate 3(a) shows these compression failures in a beam loaded for 53 days at 80 per cent of its ultimate strength and about 3 hours before final failure. The final failure of the beam is shown in Plate 3(b). The deflection-time curve in Fig. 2 for this beam, which is typical of creep of timber under constant

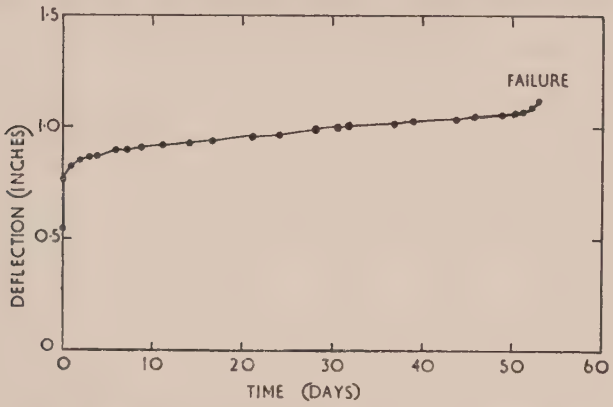


Fig. 2. Deflection-time curve for beam under a constant dead load of 80 per cent of ultimate load carried in standard static bending test.

load, has three stages of creep after the initial deflection on loading. In the first of these the rate of deformation decreases until a second stage of almost constant creep occurs. In the third stage the rate of deformation increases up to the final failure of the specimen.

WOODWORKING

WORKING PROPERTIES OF HOME-GROWN SOFTWOODS

An investigation of the working properties of home-grown Sitka spruce has been made with the object of relating those properties to the geographical region and Quality Class of the site producing the trees. The working properties of the timber were assessed on the quality of the finish of 4-in. tongued and grooved flooring strip, which had been machined in accordance with standard commercial practice, and on its ease of working as indicated by the power required in ripsawing.

The quality of the machined surface of a softwood may be degraded by four defects: tearing or chipping out of the grain, raising of the grain resulting in either the spring wood or summer wood bands projecting above the cut surface, a woolly or fuzzy finish and chip-bruising. In general, the defects become more severe as the moisture content of the timber is increased, as the cutters become dull, and as the feed speed of the machine is increased. In addition, a change in the moisture content of the timber after machining alters the severity of the defect known as grain-raising. Under "commercial conditions" of working and

usage softwoods are machined, usually at fast rates of feed, at a moisture content which may subsequently either increase or decrease. These "commercial conditions" of working were simulated in the investigation to show up machining defects and to indicate possible difficulties in machine operation. The severity of the defects falling within certain areas on the surface of each piece of flooring strip was assessed from a visual inspection made with the help of the apparatus described in the 1959 Annual Report, pp. 16–17.

Analyses of the results showed that the severity of the machining defects differed significantly on timber from various sites but that the quality of the finish was not related to the geographical regions. In comparing the finish on timber machined at 12 and 20 per cent moisture content, it was found that the defects of grain-raising and, especially, of woolliness were more severe on the wetter material but that, contrary to expectations, tearing was more pronounced at the lower moisture content. No relationship was found between the density of the timber and the severity of the machining defects but the power absorbed in rip-sawing increased by about 1 per cent for every 1 per cent increase in the average density of the timber sawn.

Keen cutting edges are required to avoid an excessively woolly finish in the machining of Sitka spruce. In the production of the flooring strip, it was found that honed cutting edges were quickly broken by the relatively hard knots. Where the damage to the cutter was slight, it resulted in a general lowering of the sharpness of the cutting edge and an increased amount of woolliness. Where, however, the damage was more local and more severe, as was generally the case, it resulted not only in a reduction in the quality of the machined finish but also in the production of ridges running the whole length of the board.

The sharpness or grinding angle of the cutters in use was 35° and the result of increasing this angle to 40° was studied. It was found that although the increase in the angle reduced the amount of damage suffered by the cutter, its effect was not large enough to be worth while. As, for various reasons, a grinding angle larger than 40° is unlikely to be acceptable to machinists working softwood, the effect of increasing the sharpness angle by the operation known as jointing was explored. In this operation, a fresh set of cutting edges is ground on the cutters by an abrasive stick as it is moved along the length of the revolving cutterblock in light contact with the cutters. Such cutting edges are contained by the front face of the cutters and an arc or heel of small width which is part of the cutting circle. They, therefore, have no clearance angle and their sharpness angles are at a maximum, having a value of about 55° on the machine used in the test.

During the cutting action of the tool, the heel engages and presses on the wood to an extent which increases as the rate of feed is advanced and as the width of the heel is increased. Where the width of the heel is large, the pressure on the wood is large enough to impair the cleanness of machined surfaces and to cause pronounced grain-raising on softwoods. It is generally considered that the width of the heel should not exceed 0·030 in. for satisfactory machined surfaces. Experiments with the Sitka spruce showed that the large sharpness angle of jointed cutters made their edges practically immune to damage by knots and that, in comparison with honed cutters, their use resulted in an improvement in the finishing of the timber, provided that the width of the jointing heel was not greater than about 0·015 in.

COMPARISON OF TOOL SHARPNESS

In order to determine which of two or more steels is the most suitable for a

particular tool, it is useful to know the relative bluntness of cutting edges formed in those steels after they have cut similar amounts of wood. In general a comparison of the bluntness of the cutting edges may be obtained from measurements of the force or power required in cutting, or from the amount of metal worn from the cutting edge of the tool.

The volume of metal that has been removed from a cutting edge in blunting is difficult to compute accurately, for it requires a knowledge of the profile or cross-sectional shape of the edge. Where, however, the amount of blunting is fairly small and has not been caused by material containing silica or other abrasive agents, the profile of the edge appears as a smooth rounded curve with the two faces of the cutter forming the edge tangential to the curve. Under these circumstances, the distance that the blunt edge has receded along the bisector of the angle between the two faces forming the edge, i.e. the sharpness angle, may be regarded as a measure of cutter wear and may be used to determine the volume of metal worn from the tool.

Where a tool is equipped with many cutting edges, as for example a circular saw, the wear on the teeth is affected by the concentricity of the saw and by the uniformity of its sharpening and even under laboratory conditions wear is unlikely to be even. An estimate of the bluntness of the tool must therefore be based on the wear that has occurred on all the edges and some means of measuring this individual wear quickly is needed. To enable the relative bluntness of several saws to be compared readily, the recession of the individual tooth points with wear was measured with the aid of a microscope fitted with an eye-piece measuring scale, aligned on the bisector of the sharpness angle of the teeth. The scale was aligned on the bisector by means of two cross-wires fixed to the scale and containing the angle of the tooth point.

STRESSES IN CIRCULAR SAWS

The performance of a circular saw depends on the design and sharpening of its teeth and on the condition of stress in the blade. To enable the teeth to resist deflection by the cutting forces, the band of metal immediately below the teeth must be in a stretched or tight condition. This tightness at the rim is obtained through the elongation of the metal in the central portion of the blade by hammering on an anvil. It is augmented by the stresses set up in the blade when it revolves and is reduced by the temperature gradient set up across the radius of the saw by the heating of the teeth during the cutting action. The degree of tensioning is assessed in practice by the distance which the blade drops away from a straight edge placed along a diameter or radius at right angles to the line of two supports holding the saw in a horizontal position.

Ad hoc tests have shown that the stress condition of a saw blade has a large effect on its performance and that highly stressed saws having teeth of long pitch are capable of cutting dense hardwoods. Normally, the tooth pitch used for such timbers is relatively short, and the advantages of being able to effect some increase in the length of the pitch are a lower power demand and an increase in the service life of the saw before the need to resharpen.

It therefore appears that the selection of a tooth design for a particular application should be accompanied by some indication of the condition of or amount of stress in the blade. Unfortunately, the method of assessing the condition of the saw with straight edges gives no indication of the stresses in the blade and it is possible that the stresses may be dangerously high in saws which have been heavily hammered. A programme of research has therefore

been initiated to determine the stresses in circular saws and the effect of tooth design on the heating of the blade in cutting.

WOODWORKING PROPERTIES

Full scale tests have been carried out to determine the machining and nailing properties of white seraya, a species of light red seraya and *Khaya grandifoliola*. Limited tests have also been undertaken on lodgepole pine and Turkey oak.

THEORY OF CUTTING

Rectilinear Cutting. A report of the work carried out on the low and high speed cutting force machines has now been published [15]. No further research has been undertaken on the low speed machine but some additional tests, all cutting along the grain, were made on the "Whirling Arm" machine whilst it was adapted for speeds in the 20–100 ft/min range. Others including the examination of cutting at other directions to the grain are in progress with the machine in its present form (speed range 200/1000 ft/min).

Rotary Cutting. Since most commercial woodworking machines use some form of rotating cutter block it was considered desirable to investigate the forces acting during rotary cutting. An experimental rig for the measurement of these forces was designed and constructed. This incorporated a dynamometer to hold the test specimens and measure the forces exerted by the cutter block, parallel to and normal to the cut surface. As with the low speed machine for rectilinear cutting the cutter block was moved over the test piece held in the dynamometer.

A preliminary investigation using this experimental rig is in progress. In the first instance as an aid to the interpretation of the force diagrams a study of the formation of the "horn shaped" chip, typical of rotary cutting, is being carried out using three cutting angles, and a range of feed speeds. High speed photography is used to examine the effect of variation of feed speed on the chip formation. Typical examples of chip formation at a constant feed speed are shown in Plate 4(a) to (c). At a cutting angle of 30° a long chip is formed by riving in successive stages, ahead of the cutting edge, and there is little compression of the chip. Some protruding fibres are apparent in the back face of the chip; they have been torn out of the finished surface of the sample, degrading it. Reduction of cutting angle to 20° and 10° gives a chip formation where riving is completely absent. The chip is formed mainly by compression failure and there is a considerable shortening in chip length with a corresponding increase in the quality of the surface finish.

FOREST TOOLS

At the May meeting of the F.A.O. study group on the Testing of Forest Machinery, the protocol for the testing of power chain-saws was modified.

The test apparatus used at the Laboratory has been largely rebuilt and it is now in a more permanent form. During a visit to Finland, an officer of the Section was able to study the test techniques and apparatus used for the official chain-saw tests there. The basic principles of these tests were found to be the same as our own.

The scope of the present tests has been extended to cover further sections of the F.A.O. protocol. Additional work on those chain-saws which had already been tested is therefore in progress. Future chain-saws will receive the complete series of tests.

SAWMILLING SURVEY

Work on the sawmilling survey was confined during 1959 to the monitoring of all literature on the subject, and to visits to some sawmills in Wales. Other information was obtained during a visit to Germany, Sweden and Finland (see Visits Aproad, p. 3).

COMPOSITE WOOD

STUDIES OF GLUES AND GLUING

(a) *Durability of adhesives*

Series V. Tests on plywood exposed to weather for five years have confirmed[16] that only the phenolic type of adhesive is suitable for such service. This had previously been established for phenolics setting at 145°C and used with birch, beech, African mahogany, gaboon, etc. New data relate also to a phenolic adhesive setting at 115°C used for gluing African mahogany. Doubt has been expressed however whether these lower-temperature phenolics will be equally satisfactory when used with the denser and stronger beech, for they do not in general give as high an initial knife test[17] rating with this species as those set at 145°C. Although beech finds little use in the British plywood industry, it is not a species that should be neglected, and tests have been set up to investigate the durability of six brands of 115°C phenolic glues used with beech.

High temperature effects. There is continued interest in the influence of high temperatures on the durability of glued joints. The effect of oven-drying at 100°C for periods up to four weeks was investigated with one brand of each of four types of cold setting synthetic resin adhesive. Standard beech test slips were given this oven-drying treatment, and after reconditioning, were made into lap joints. The report[18] showed that the wood itself was unaffected by the heating. Prepared glued joints were then similarly treated, and no loss of strength was found with urea and phenolic glues, but resorcinol and resorcinol/phenolic adhesives underwent a loss in joint strength of 12 and 9 lb a week respectively from an initial value of about 600 lb in the wet test. It is planned to continue these tests at 100°C but with different levels of sustained humidity.

(b) *Variability in glue testing*

Since its introduction in 1942[19] the close-contact lap joint made from beech slips has proved to be a satisfactory means of checking the quality of cold-setting adhesives. Anomalous results occasionally occur when the testpiece is used for purposes more exacting than specification work, and various characteristics[20] of the joint are being re-examined.

Six sets of twelve joints were made from randomised slips of high quality using one mix of each of three types of glue. The joints were tested at intervals up to four weeks after manufacture. The tests were later repeated with similar slips but using different mixes of glue, although the resins and hardeners were from the same batches. Statistical analysis showed that all three types of glue were of different bond strengths and that there was a significant difference between the original and the repeat tests. With the two urea resins, extending the conditioning period from 3 to 28 days was without effect on both mean failing load and the scatter of individuals, but with a resorcinol glue there was an increase of 55 lb in about 750 lb over the four weeks. From the data, confidence limits for the mean failing load with various numbers of test-pieces were evaluated and are recorded in Table 1.

These are the maximum amounts by which the average failing load for a sample containing a particular number of test pieces can differ from the true mean. The cases where 95 and 99 repetitions out of 100 are considered.

Table 1

Confidence limits lb for the mean failing load of B.S. 1204 *lap joints*

Number of test-pieces	6	12	24	36	48	60	96	144	180
95% level	66	43	30	24	21	18	15	12	11
99% level	93	59	40	32	28	24	19	16	14

(c) *Assessment of bond quality*

The small standard lap joint of B.S. 1204:1956 is satisfactory for testing glues but gives little scope for investigating the technicalities of gluing or for studying the meaning of bond quality as applied to a laminated article. A test unit has therefore been developed in the form of a beam 2 in. × 7 in. × 42 in. long, which is made from 14 laminations and employs 10 of the 13 glue lines for test purposes. The new unit permits the simultaneous use of four different test methods

(a) A forcible separation or chisel test.
(b) A mechanical test giving the ratio of shear strength of the glue line and the adjacent wood.
(c) Wood failure estimated for the test piece of (b).
(d) A cyclic wetting and drying test.

Details of the method of making these tests are given in a report [21] together with data obtained from sets of six beams made with three species. Table 2 summarizes the result, each figure being the mean for 240 glue lines. With any one species the value of the bond quality varies according to the test method employed. This generalization has been known for some time, but the beam test-unit is believed to be the first one designed to incorporate several methods, and its use should lead to a better understanding of the meaning of bond quality.

Table 2

The beam test-unit. Average bond qualities by the form test methods

(In each test the highest possible bond quality rates as 100 and the lowest as zero)

Species	Glue	Bond Quality by:			
		Chisel test	Shear rates	Wood failure	Cycle test
Oak	RF	41	90	72	91
Beech	PF	19	98	80	76
Scots pine	UF	84	97	92	97

Plate 5 shows the beam and the manner of cutting it into four independent test sets known as "stations", which can be used in three ways. All four can be assessed at one time if only a single problem is involved, such as the gluing

characteristics of a species. Two stations can be tested initially and two after, as for example after applying heat to accelerate the curing of the glue. In ageing tests, where repetitions at lengthy intervals are needed, a single station can be used, thus giving tests on four occasions. The last of these would require more beams than the first if the same confidence limits for the mean bond quality are to be maintained, and data are being collected that will enable predictions of the required numbers to be made.

PREPARATION OF VENEER

Bark form and veneer figure in birch. In the 1959 Annual Report pp. 23–24 a joint project with the Forestry Commission was described to see if it was possible to predict the figure within a birch tree from the appearance of the bark[22]. The results were promising and a further investigation is being made. In a single population of birch, six recognisable bark forms were found, and five trees of each were selected that ranged in age from 80 to 140 years. As in the previous experiment, these trees are being converted to veneer by rotary cutting and slicing radially, the billets having previously been marked by drilling so that veneer at any diameter and at various angles relative to the North point can be related to the over-lying bark.

So far, one tree of each of the six bark groups has been examined. The tree having bark disposed as large irregular plates, contained persistent pure flamy figure from a diameter of 3 in. At the other end of the scale, a smooth-barked log gave straight-grained veneer marred only by snail figure and by knots that could have been eliminated by pruning. With other bark forms, figure was plentiful but mixed in type, and the relation between the bark and the predominant figure has still to be established. It is apparent that bark form is much more definite in these older trees than in those of 50–60 years used in the earlier work.

Assessment of veneer quality. The quality of rotary-cut veneer is usually judged by appearance and suitability for intended use rather than in quantitative terms. This method has its limitations in research work where a measure is needed for an examination of cutting variables and in the study of causes of distortion of veneer and plywood. A survey[23] of published work showed that attempts along seven different lines have been made to assess quality, but the majority have been limited to measurement of slackness. Very little attention has been given to the equally important feature of overtightness, which by its nature, excludes methods of assessment based on appearance. Investigations for this aspect are proceeding.

Trials of timbers. The veneering qualities of Turkey oak have been investigated[24] and since the timber is in the decorative class, the work was concerned mainly with the slicing rather than the rotary-cutting characteristics. A comparison was made with European oak veneered in the same way.

The Turkey oak was found to be harsher to cut, the ray figure was smaller and not so bright, and tended to rise proud of the surface. The veneers however were less susceptible to iron staining than those of English oak.

RADIO-FREQUENCY HEATING

Influence of frequency on glue setting rates. The Annual Report for 1959 (p. 24) records a major investigation to study the function of generator frequency and other associated factors in the gluing of wood under radio-frequency heating. The experimental work is now at an advanced stage and

some tentative conclusions can be drawn. The seven-day-strength of B.S. 1204:1956 type lap joints made under glue-line heating is unaffected by the level of generator frequency but can be considerably influenced by the setting time of the adhesive. If the heating is adjusted to give setting times of under 60 seconds, then the seven-day-strength can be considerably lower than that of similar cold set material. With rapid setting, the adhesive becomes very hot before it cures and the accompanying drop in viscosity allows absorption by the wood, resulting in a starved joint. This effect can be overcome by altering the viscosity characteristics of the adhesive. The method adopted in this investigation was to add flour to the glue mix before use. Additions of up to 10 per cent are sufficient to bring the strength of radio-frequency set joints up to and, in some cases, above that of similar cold-set material.

If the joints are cured by transverse heating, then neither the generator frequency nor the setting time affect the seven-day-strength, but the moisture content of the wood can become important. With some brands of glue the radio-frequency cured joints become weaker than those of similar cold set material if the moisture content of the wood is raised to above 12 per cent. With the transverse and, to a lesser extent, with the glue-line heating, the voltage gradient between the electrodes necessary for a cure in any one setting time is very dependent on the generator frequency. Theoretically the radio-frequency power supplied to a wood-glue assembly is proportional to the frequency, to the voltage gradient between the electrodes and to the electrical constants of the composite. This investigation indicates, however, that for the theoretical equation to be satisfied, the electrical constants of the wood-glue composite must change rapidly with frequency over the range 5 to 25 Mc/s. The electrical constants of wood alone change but slowly with frequency, so it seems that the amount and type of adhesive in the composite has considerable influence on the power absorbed at any one frequency.

The electrical constants of wood-glue composites. The electrical behaviour of a dielectric under radio-frequency heating is controlled by two constants, the permittivity and the loss tangent, both of which are dependent on the frequency of the generator. These constants can be measured in a number of ways, but probably the simplest and most convenient is with a circuit magnification or Q meter connected to a sample holder designed to accommodate the material being examined[25]. A Q meter has been obtained and a sample holder constructed for making measurements of the permittivity and loss tangent of wood-glue composites (Plate 6). The sample holder consists essentially of two rectangular plates, one of which is insulated electrically from the other. The wood-glue composite is placed between the plates and thus acts as the dielectric of a parallel plate capacitor. It is then possible, by means of the Q meter, to measure the permittivity and loss factor of this capacitor and hence of the wood-glue composite. This technique has been proved satisfactory and is now being applied to such investigations as the effect of the fringing of the electric field at the edges of the test capacitor on the measurements and the influence of small variations in the sample size.

The measurements of radio-frequency power. The power consumed in a load under radio-frequency heating can be obtained from a knowledge of the voltage gradient between the electrodes, the generator frequency, and the electrical constants of the wood-glue assembly. In all but the simplest loads, however, assumptions have to be made which can have considerable effect on the

calculations. To overcome this source of error the use of a radio-frequency wattmeter is being considered that will give an immediate indication of the power being consumed in the load. A design has been evolved in collaboration with the National Physical Laboratory and is covered by a provisional patent[26]. The instrument consists essentially of a thin rectangular crystal of a semi-conductor mounted between two flat parallel transmission lines connecting the radio-frequency generator to the load. The magnetic field between the lines cuts the face of the crystal and a voltage proportional to that between the lines is applied to two opposite edges. Then, because of the Hall Effect, the output from wires attached to the two unoccupied edges of the crystal is the product of the voltage and the currents and is thus a measure of the power flowing in the transmission lines.

WOOD PRESERVATION

PERMEABILITY OF SITKA SPRUCE

An assessment of the permeability and resistance to impregnation of home-grown Sitka spruce has been made as part of the investigation into the properties of this timber and their variation with the region of growth and Site Quality Class. Timber of two or three Quality Classes from each of six regions has been examined. All of the material proved to be resistant to impregnation and no significant difference was found between the timber from the different regions. In general the sapwood was considerably easier to impregnate than the heartwood, although, with the timber from one region, it was almost as resistant as the heartwood.

The timber from all regions has a tendency to collapse under the treatment used. The incidence of collapse was found to depend primarily, if not entirely, on density, and with the material from all the sources the degree of collapse increased as the density decreased. Because of its lower average density it will be necessary to treat Sitka spruce under slightly milder temperature/pressure combinations than are used for commercial treatment of imported softwoods, but if this precaution is taken there needs be no trouble from collapse.

TREATMENT BY IMMERSION

Various aspects of this method of treatment have been described in the Annual Reports for 1957 (pp. 26–27) and 1959 (pp. 28–29). The object of recent work on this project has been to investigate the extent to which the properties of the preservative control the depth to which it penetrates the wood. On theoretical grounds the penetration would be expected to be proportional to $[\gamma/\eta]^{\frac{1}{2}}$ where (γ) is the surface tension of the preservative and (η) its viscosity, assuming that the angle of contact between the preservative and the cell wall is zero or nearly so, i.e. that the preservative wets the wood properly. The results of earlier work indicate that a relationship of this type existed, but it was only an approximate one; moreover, one or two preservatives, notably those of the water-borne type, obviously did not conform to it at all.

It has now been established that this relationship holds closely for the first stage of the penetration—that which occurs during the actual period of immersion—provided the preservative is a non-polar one which penetrates only into the cell cavity and is not absorbed into the cell wall (see Fig. 3). All of the common oil and organic solvent preservatives are of this type. The second

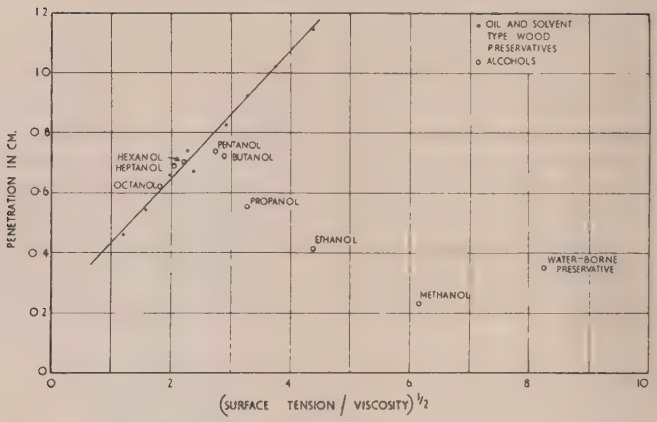


Fig. 3. Relationship between the lateral penetration of solvent type preservatives and their physical properties.

stage of penetration—that which occurs after the wood has been removed from the preservative—and which constitutes 20–45 per cent of the final depth, is also primarily a function of surface tension and viscosity, but it is now influenced also by the volatility of the preservative since evaporation reduces the quantity of preservative available for further penetration, and may also increase its viscosity.

The penetration of water-borne preservatives does not conform to this relationship, and is very much less than would be expected from their high surface tension and low viscosity. This was found to be true also of other polar liquids which, like water, are absorbed into the cell wall. One explanation of this could be that when liquids of this type travel along the cell cavity they are being continuously depleted by absorption into the wall, and therefore penetrate more slowly than a non-polar liquid with a similar surface tension/viscosity quotient which would not be absorbed.

A most interesting illustration of the dominating influence of polarity or cell wall absorption on penetrating power is provided by the behaviour of the homologous series of alcohols from methanol up to octanol. An alcohol consists of a non-polar paraffinic chain terminating in a polar hydroxyl group. The lower members, methanol and ethanol, have polar properties and are readily absorbed by the cell wall, and, as will be seen from Fig. 3, penetrate the wood to a much smaller extent than a non-polar liquid with the same surface tension/viscosity quotient. As the series is ascended, however, and the paraffinic chain increases in length, the molecule becomes increasingly non-polar in character, and the fifth member, pentanol, and above are no longer absorbed by the cell wall. The penetration into the wood now agrees with the relationship established for non-polar preservatives and liquids.

Another feature of water-borne preservatives which was found to hinder their penetration during immersion treatments is that they do not "wet" wood as readily as organic liquids. This is evident if drops of water and methanol, both polar liquids, are placed on the machined lateral surface of a permeable wood. The methanol spreads out instantaneously and is quickly absorbed, but the water remains as a drop for some considerable time and is only slowly absorbed into the wood. With liquids which "wet" the wood readily the contact angle θ

between the meniscus and the cell wall is zero. Microscopic examination of thin sections of wood during penetration showed that with water there can be an appreciable, and sometimes large, contact angle. The capillary pressure which drives liquids into the wood is proportional to cos θ and therefore the pressure and in turn the penetration, is reduced if θ is appreciably greater than zero.

The contact angle can be reduced by adding a wetting agent to the water and therefore an increased penetration would be expected. Wetting agents however also reduce the surface tension and this has the effect of reducing the penetration and thus reducing, or reversing, the advantage gained. Tests showed that wetting agents do give a small improvement in penetration during the early part of an immersion treatment, but it is doubtful whether they would be of much value in practice.

The basic information obtained from this investigation, on the mechanism of penetration of preservatives during an immersion treatment will be of value both in treating practice, and also in the laboratory when carrying out accelerated tests aimed at assessing the fungicidal or insecticidal value of a preservative applied by dipping. The results of the investigation also give some guidance on the physical properties to aim at in formulating a preservative to obtain the best penetration from a non-pressure treatment. The preservative should not be absorbed by the cell wall and should have a fairly low vapour pressure and as high as possible a value for the surface tension/viscosity quotient. There is little difference in the surface tension of suitable non-polar solvents, so that this last requirement amounts in practice to achieving as low a viscosity as possible. A report on this work is being prepared.

Forest Products Research Record No. 31 has been prepared[27] to include the information of direct practical value obtained from this investigation.

LOSS AND MOVEMENT OF CREOSOTE IN WOOD DURING SERVICE

As suitable material becomes available studies are being made on the movement, loss, and changes in composition that may take place with creosote during service, in order to gain more knowledge on certain aspects of its preservative action. In last year's Annual Report (pp. 25–27), work was described which showed that in a redwood post the loss of creosote above ground line is much greater than that below and that this is due partly to different rates of loss by evaporation and partly to a downward flow of creosote towards the butt. Work is now in progress to determine whether the residual creosote has lost any of its preservative value and, if so, whether this occurs to the same extent above and below the ground line. Samples of creosote have been recovered from above and below the ground line and their toxicity is being determined. So far the indications are that the residual creosote is still highly toxic after 30 years in service.

PENETRATION OF OIL AND WATER-BORNE PRESERVATIVES INTO REDWOOD DURING PRESSURE TREATMENT

The bulk of the timber pressure treated with preservatives in this country consists of a few softwood species, principally redwood, Douglas fir and whitewood. A great deal of practical experience has been gained on the treatment of these timbers, but existing knowledge of their amenability to impregnation with preservatives is still mainly of a general, empirical nature and certain important quantitative data are lacking. There is, for example, no information on the average depth of preservative penetration which can be expected from a

stated period of treatment, nor on how much this varies between different pieces or different consignments of the same timber. Such data are essential, for example, in deciding what standards of treatment can reasonably be expected in preservation practice and for drawing up satisfactory treating specifications.

Some time ago there occured an opportunity to obtain material from some thirty consignments of redwood collected from all the main areas in the Baltic from which this timber is at present obtained. Samples from all these consignments have been pressure treated with creosote and with a water-borne preservative and data have been obtained on the depth of preservative penetration achieved with different periods of treatment which should be applicable to the timber as a whole. These are shown in Table 3.

Table 3

Lateral penetration of preservatives in redwood

(in inches)

Time under pressure (hours)	Creosote		Water-borne	
	Average	Range*	Average	Range*
1	0·47	0·22–0·72	0·22	0·06–0·38
2	0·69	0·31–1·03	—	—
4	0·81	0·31–1·38	0·28	0·09–0·47

(* The range has been computed from the standard deviation and defines the limits within which it is estimated that 95 per cent of all redwood treated would fall.)

Two important points have emerged from this work. The first is that redwood can be impregnated with creosote much more deeply than is generally believed. The second is that it can be penetrated much more deeply with creosote than with a water-borne preservative. This second result is unusual as in general it is believed that most timbers are penetrated to about the same extent with oil or water-borne preservatives. Data on the permeability of redwood, determined from gas flow measurements, indicate that it is not the water-borne preservative that is penetrating less than it should, but that the creosote is penetrating more. The greater penetration of creosote appears to be the result of its ability to penetrate much more deeply along the rays. These contain horizontal resin ducts and it is believed that penetration is facilitated by removal of the resin by solution in the creosote. The very ready solubility of the resin from redwood in both hot and cold creosote was established by extracting it from the wood with ether and checking its solubility in creosote directly.

The treatments mentioned above were carried out in accordance with accepted practice, i.e. with the creosote hot (180°F) and the water-borne at about atmospheric temperature. In order to confirm however that the smaller penetration of the water-borne preservative was not in any way due to operating at a lower temperature matched samples were treated at 180°F also with a heat stable water-borne solution but no better penetration was obtained.

It seemed probable that this higher permeability to creosote might not be confined to redwood but might be a general characteristic of the genus *Pinus*. So far it has been possible to check this with two more species only namely Caribbean pitch pine and lodgepole pine. Both of these showed a higher

permeability to creosote, the pitch pine to an even greater extent than redwood, but with the lodgepole pine it was less pronounced. Thus although it will have to be confirmed for other important *Pinus* species the indications are that it is a characteristic behaviour of the genus and not of redwood alone.

This work has shown that the heartwood of redwood can be deeply penetrated with creosote, and has brought out how very suitable this, and certain other species of *Pinus* are, for purposes where a high standard of preseravtive treatment is required.

DISTRIBUTION OF PRESERVATIVES IN TREATED WOOD

In investigations carried out in the laboratory on preservatives, insecticides and fire retardants it is frequently necessary to prepare wood samples containing a range of different loadings of these materials. This is done by impregnating the samples with different strength solutions of the preservative or other substances in a suitable volatile solvent which can be conveninently removed by evaporation. Some of the solvents which are commonly used are water, benzene, toluene, acetone and chloroform. This form of treatment is used in Europe and in the United States in the standard method for measuring the toxicity of preservatives to wood-destroying fungi, and it has also been widely used in toxicity work against insects.

Some time ago its use for controlling the loadings of creosote and other organic preservatives in the larger type samples used in field service tests was investigated. It was found [28] that the evaporation of the solvent caused the preservative to migrate to the surface of the wood. Subsequently it was shown that this uneven distribution occurs also with the small wood blocks used in toxicity work. It has since been found that this migration occurs with a variety of preservative materials and it is now believed that it always occurs to a greater or less extent, except with preservatives which undergo chemical reaction when they are within the wood and can become fixed before appreciable evaporation of the solvent has occurred.

The very marked unevenness in distribution which this method of treatment can produce must give rise to uncertainty as to what the effective loading in the wood actually is. At present this method of treating with various strength solutions in a volatile solvent is the only way there is of obtaining a wide range of predetermined loadings of a preservative or other substance in timber samples and since the above findings were made various modifications have been considered, or tried, in attempt to obtain a more uniform distribution. The migration of the solute is the result of bulk movement of the solution towards the surface, caused by capillary forces, and it was concluded that the only way of preventing it would be to immobilize the solution during the time the solvent was evaporating. The only practicable way of doing this appeared to be to freeze the solution in the wood and sublime off the solvent under vacuum. Very few solvents have suitable freezing points for doing this conveniently, but the most promising was benzene, which freezes at 5·5°C and has a fairly high vapour pressure. Fortunately it is a satisfactory solvent for most, if not all, of the organic preservatives.

Tests have been carried out with solutions in benzene of three common preservatives, namely creosote, copper naphthenate and pentachlorophenol. After impregnation with these solutions the samples were dried under vacuum at about 0°C to remove the benzene. After drying in this way all three preservatives appeared to be uniformly distributed throughout the samples and showed

no evidence of the steep concentration gradients always found in air dried samples. Plate 7(a) shows samples dried by both methods. The distribution of one of the preservatives copper naphthenate was also determined by analysis.

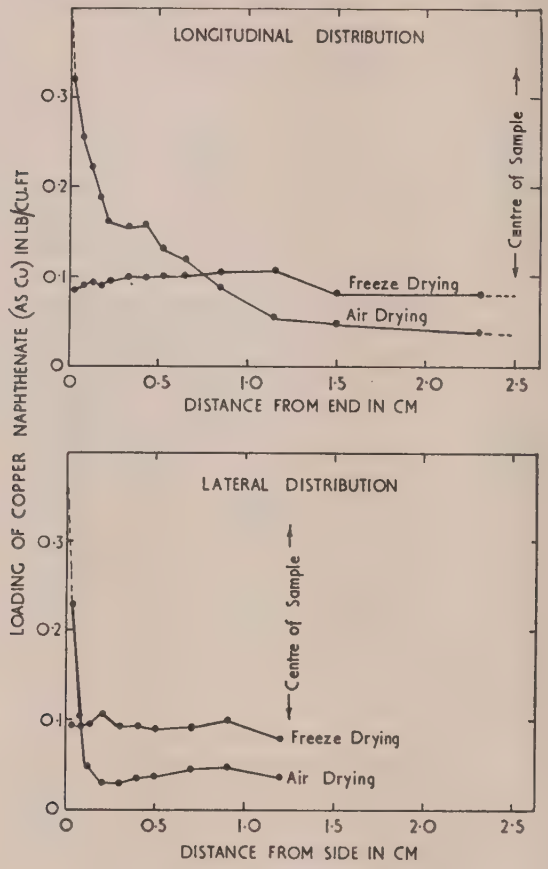


Fig. 4. Distribution of copper naphthenate in a 5 × 2·5 × 1·5 cm block after (a) air drying, (b) vacuum freeze drying.

As will be seen from Fig. 4, it proved to be reasonably uniform in the freeze-dried samples but in the air dried ones there was a very steep concentration gradient near both the longitudinal and lateral surfaces. It is considered that this method of removing the solvent provides much more satisfactorily treated samples for most of the various laboratory testing procedures for preservatives, particularly for those of toxicity against fungi and insects, than is possible with air or oven drying which is now used. Later it is hoped to check this by comparative tests run on samples prepared by two methods.

Drying by this method will probably take somewhat longer than at present but measurement of actual drying rates have not yet been determined with proper refrigerated, high vacuum drying facilities.

A note on this work has been prepared[29].

MYCOLOGY

CULTURE COLLECTION

The culture collection has been maintained and eleven new cultures of wood-destroying fungi have been added. Eighty-two cultures have been supplied upon request and twenty-eight, including a number from East Africa and Australia, have been received for identification.

NATURAL DURABILITY TESTS

Timber investigated. In view of the possible future importance of lodgepole pine as a timber species for planting in Britain natural durability tests have been carried out on home-grown timber. The results have confirmed the general reputation of the species for low decay resistance. The material tested was classed as non-durable. Natural durability tests have also been carried out on home-grown Turkey oak. The results showed that although the heartwood of the timber is slightly more resistant to decay than sapwood it can only be rated as non-durable.

Tests on normal and tension wood of *Khaya grandifoliola* and *Khaya ivorensis* have shown that tension wood in both timbers is more resistant to decay by the white rot fungus *Polystictus versicolor* than is normal wood. There was little variation in resistance of normal and tension wood to the brown rot fungus, *Coniophora cerebella.*

The sawdust method for assessing natural durability. In order to overcome the difficulty of obtaining standard size test blocks in sufficient quantities from clearly defined zones in small home-grown trees, consideration has been given to the use of sawdust samples for natural durability testing. Consistently good results have been obtained with European spruce sawdust using Da Costa and Rudman's method[30]. The observation has been made that much more rapid attack of the sawdust occurs when the tests are conducted in culture bottles laid horizontally on their sides instead of in bottles incubated in the normal upright position (see Fig. 5). The hypothesis that accumulation of carbon dioxide hinders decay in bottles incubated in the upright position will be tested.

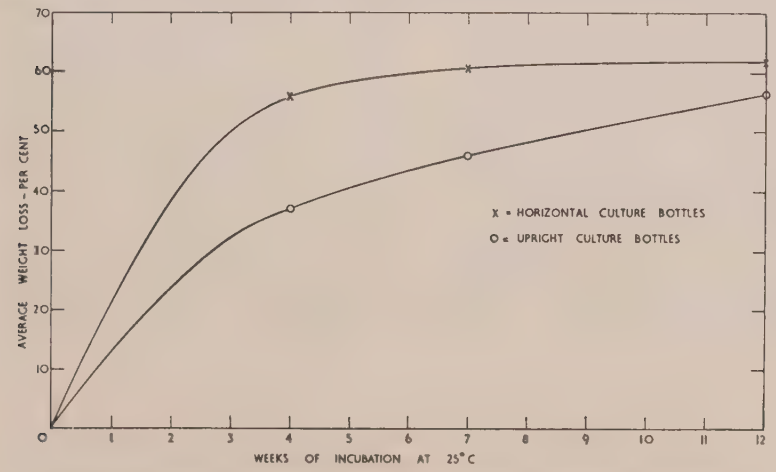


Fig. 5. Decay of European spruce sawdust by *Conipohora cerebella.*

An extractive from Indian rosewood. The polyphenol extracted from Indian rosewood which was toxic to wood-destroying fungi at concentrations in agar of 0·03 per cent (see the Annual Report for 1959, p. 31) has been further tested by exposure to attack of blocks of beech wood impregnated with solutions of varying concentration. Surprisingly, in the wood no indication of toxicity was obtained and blocks impregnated with a 1·5 per cent solution decayed as rapidly as untreated controls.

WOOD PRESERVATIVES

Work has begun on the determination of the toxicity of creosotes extracted from treated poles which have been in service for a thirty year period. Tested by the agar plate method the toxicity of the aged creosotes was more than fifty times lower than that of normal creosotes, which agrees with earlier work using this method[31]. However, using the more reliable wood block test method[32] there are indications that the toxicity of the aged creosotes in wood is broadly comparable with that of normal creosote. The precise toxic limits of the aged creosotes in wood have yet to be established. The results to date are of considerable interest as they differ from the generally accepted view supported by agar test results that as the more toxic constituents of creosote are also the most volatile their earlier loss in service leads to marked reduction in toxicity of the residue.

Long term tests of the residual toxicity of surface applied preservatives have been continued. Treatments with a brushing creosote and 4 per cent sodium pentachlorophenate remain effective after $3\frac{1}{2}$ years but 5 per cent sodium orthophenylphenate treatment showed some indications of failure after 3 years.

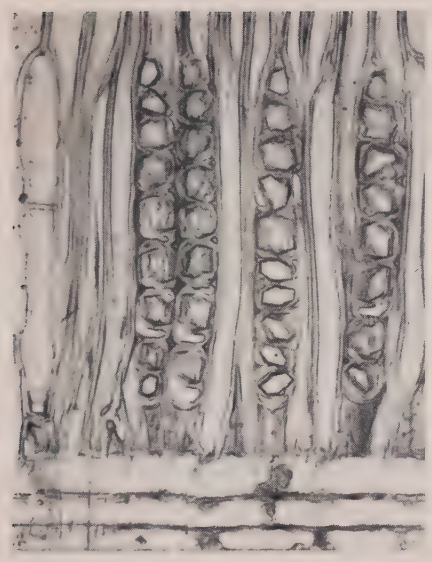
Examination of field test stakes to determine the causes of failure has been continued. Where Basidiomycete failure is the obvious cause of decay in preservative treated stakes attempts are being made to grow in pure culture the fungus responsible for failure.

SOFT ROT

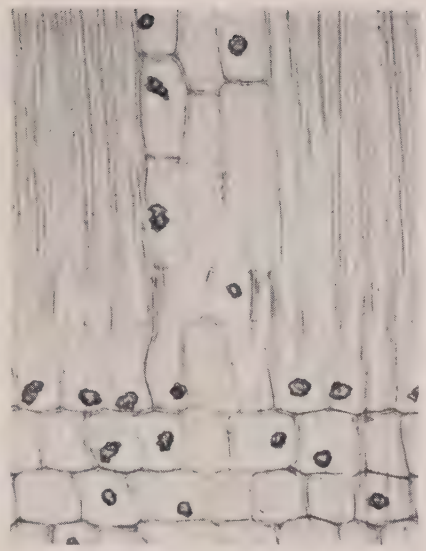
The investigation has been completed on the susceptibility of chlorine treated wood to attack by *Chaetomium globosum*. The treatment of Californian redwood heartwood in low concentrations of chlorine water (average 22 parts per million) at room temperature for periods of up to fourteen days failed to stimulate attack of the wood by soft rot organisms. Scots pine sapwood which was attacked slowly by *Chaetomium globosum* in pure culture and rather more severely in soil fungi in mixed culture was no more susceptible to attack after chlorination or comparable leaching in water alone. Leaching increased the susceptibility of beech to attack but chlorination of beech did not lead to any greater increase in attack than did leaching alone.

The fungus *Trichoderma viride* commonly regarded as a harmless timber mould has frequently been isolated from wood showing decay of the soft rot type but several experiments have failed to demonstrate that it is capable of attacking the wood. Following a report[33] that it had been shown to cause decay of the soft rot type and appreciable strength loss further trials have been carried out, again with negative results. It would appear that the status of this organism must, for the time being, remain open to question.

The previous report (see the Annual Report for 1958, p. 31) that there are soft-rot organisms more tolerant of creosote than *Chaetomium globosum* has been confirmed. The toxic limits of creosote to two organisms, *Humicola grisea*

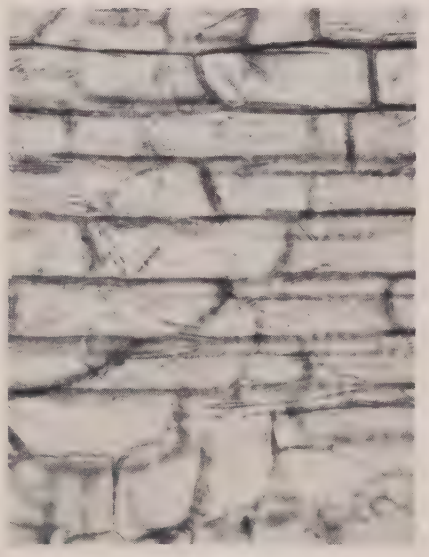


Pterocarpus soyauxii (×200)
Rhomboidal crystals in ordinary cells



Dicorynia paraensis (×200)
Silica aggregates

Terminalia superba (×200)
Elongated crystals



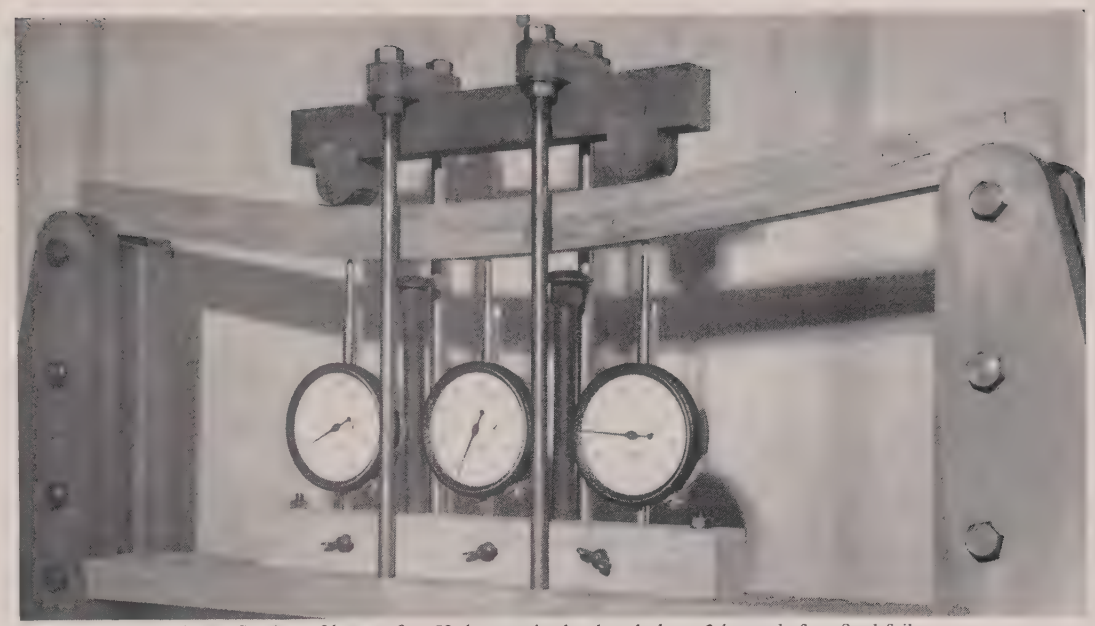
Gmelina arborea (×400)
Acicular crystals

Photomicrographs illustrating some of the crystal features used in Forest Products Research Bulletin No. 46, "Identification of Hardwoods. A Microscope Key"

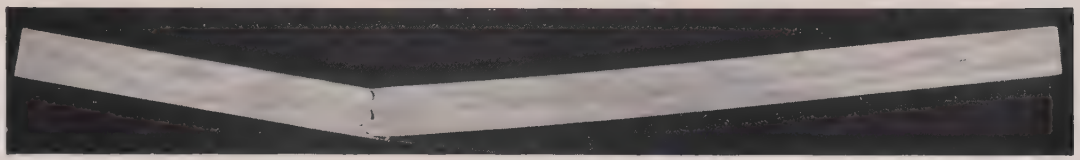
PLATE 1

Roofed and unroofed stacks of Sitka spruce used in the air drying experiments at Strachur

PLATE 2



(a) Deflection of beam after 53 days under load and about 3 hours before final failure

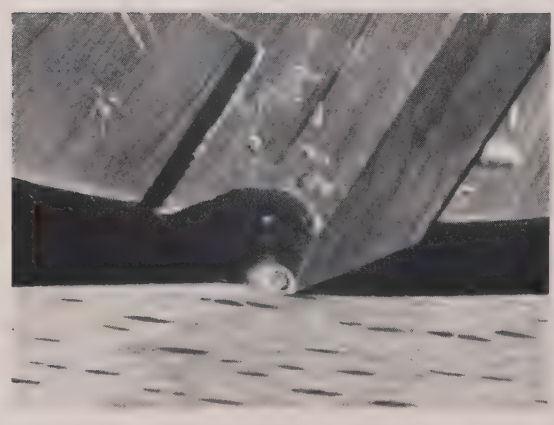


(b) Final failure of beam

A beam loaded to 80 per cent of the ultimate load carried by matched specimens in the standard bending test

PLATE 3

(a) 30° cutting angle
(10 ft/min)



(b) 20° cutting angle
(10 ft/min)

(c) 10° cutting angle
(10 ft/min)

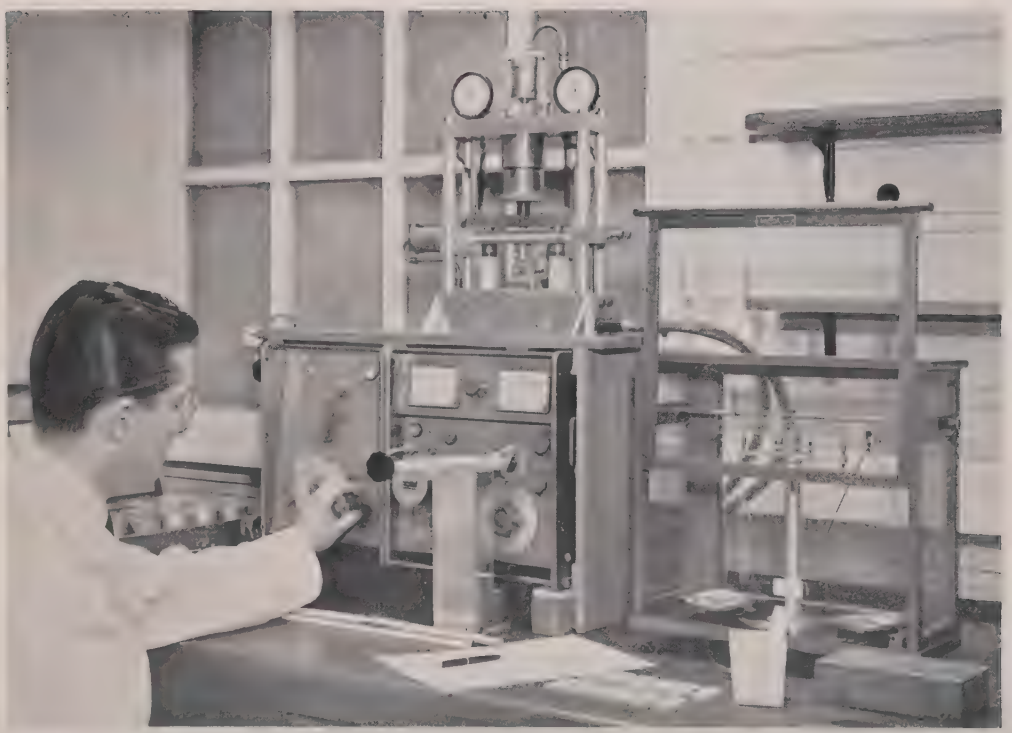
Effect of cutting angle on chip formation ($\times 3$)

PLATE 4

1. The 42-in long beam and its reference marks for face and edge. 2. Discs and blocks at the four stations. Mating faces of discs are marked. 3. The chisel and the disc. 4. Disc after chisselling. 5. Mirror image of wood fibre and adhesive across a glue line. 6. Grid to aid assessment of bond quality. 7. Disc sheared at glue line. Used also for wood failure assessment. 8. Disc sheared in the wood. 9. Block after cycle test

The beam test unit

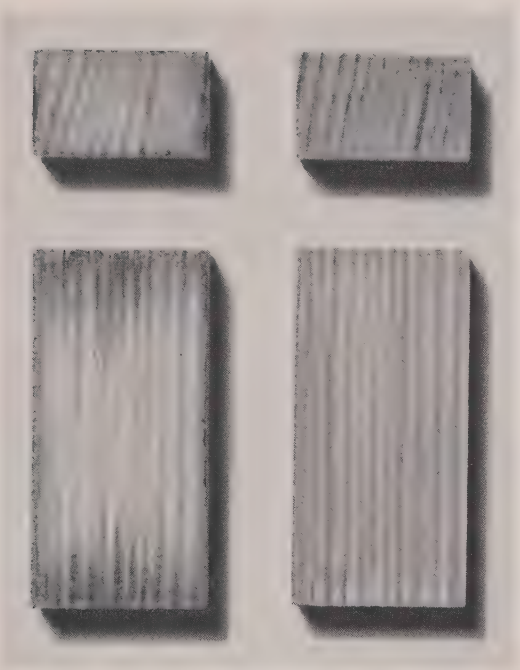
PLATE 5



The sample(s) is held between the plates of the sample holder which is linked by a low capacitance co-axial transmission line to a circuit magnification meter

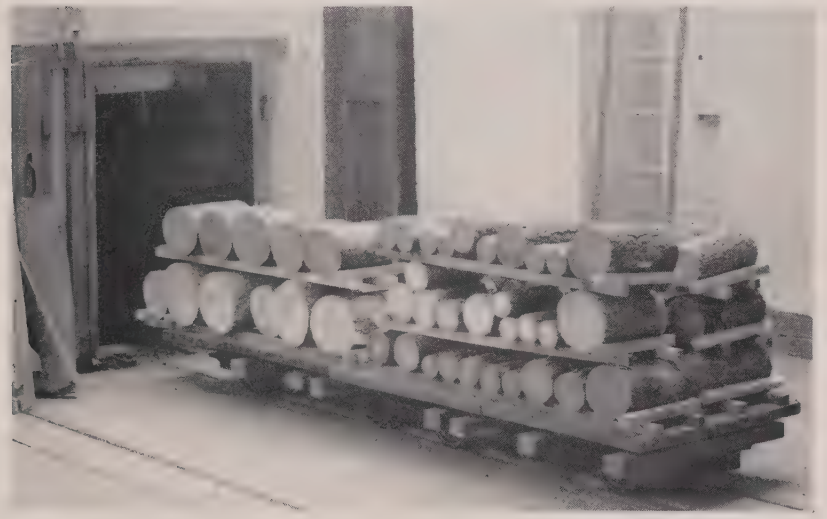
Apparatus for measuring the electrical constants of wood-glue composites

PLATE 6



Air dried Vacuum freeze dried

(a) Sections of Scots pine sapwood blocks impregnated with copper napthenate in benzene, after removal of solvent



The billets with dark end surfaces have been creosoted. The remainder are untreated controls on which surface growths of blue stain fungi have developed

(b) Billet trial of creosote as a protectant against blue stain in logs

PLATE 7

Eggs of Paratillus carus (×25) in vessels of European oak sapwood

PLATE 8

and *Sporocybe* sp., isolated during the course of the previous tests have been established by the wood block method as 6·9–14·3 kg/m³ contrasting with those to *Chaetomium globosum* of 3·8–7·2 kg/m³.

SAP STAIN INVESTIGATIONS

Prevention of staining of felled pine logs has been a major topic of experimental work during the year. Visits have been made to Thetford Chase forest to assess the incidence of blue stain in logs held in store there. *Ceratocystis coerulescens* and *Leptographium lundbergii* were the major causes of staining in samples collected for laboratory examination. *Diplodia pinea* was found fruiting on surfaces exposed by bark scrapes on many of the samples examined, but the light blue stains caused by this fungus were neither extensive nor prominent in the wood.

As creosote is already employed in the forests for treating pine stumps to control spread of the pathogenic fungus, *Fomes annosus*, attention has been directed towards its possible use to prevent entry of stain into the felled logs. Trials under forest conditions are being planned but as they take many months to conduct, laboratory trial methods are being elaborated to obtain more speedy assessment of creosote and other log protectants. Use of 12 in. long billets of freshly sawn timber as test material has yielded interesting results. The billets are end treated and together with untreated controls (see Plate 7(b)) are maintained under controlled conditions of temperature and humidity in a kiln for periods of up to three months. A high potential of infection is maintained by spraying the test material with a suspension of spores of staining fungi at weekly intervals.

Less effective protection has been obtained with a low tar acid creosote than with the high tar acid creosote currently used against *Fomes annosus*. The latter prevented entry of the faster growing staining fungi over the three months test period, but there are indications that the creosote tolerant fungus *Hormodendron resinae* is able to pass through the protective treatment and cause limited staining. There are indications that in treated Corsican pine sapwood billets faster growing staining fungi may enter via the pith into which the creosote does not readily penetrate. It has been noted incidentally that end treatment with creosote retards the rate of drying of the billets.

The toxic limits in agar of sodium pentachlorophenate and sodium orthophenylphenate towards the more common blue-stain fungi have been determined. A few chemicals of potential value for prevention of staining in logs have been tested in the Laboratory to determine the concentration at which they effectively prevent staining of freshly sawn green Scots pine sapwood.

The growth-temperature relations of the more common staining fungi have been determined. Salient features are recorded in Table 4.
The relative frequency of occurrence of *Leptographium lundbergii* and *Ceratocystis coerulescens* in the forests is probably related to their faster growth over a wide range of temperatures. The high optimum temperature of *Diplodia pinea* was anticipated as this fungus is best known as a sub-tropical species and its prevalence at Thetford in the winter of 1959/60 was probably a consequence of the very hot weather during the summer of 1959.

MISCELLANEOUS WORK IN MYCOLOGY

Amongst the more unusual problems upon which advice has been given have been development of blue stain in wooden backs of bath brushes, decay of

Table 4

Temperature relations of common sap stain fungi

Fungi	Optimum temperature	Daily growth rate on agar (diametric) in cm	
		At optimum temperature	At 10°C
Leptographium lundbergii	26°C	2·4	0·5
Ceratocystis coerulescens	24°C	2·3	0·8
Diplodia pinea	28°C	2	0·3
Macrophoma strobi	24°C	1	0·2
Ceratocystis pilifera	26°C	0·8	0·3
Sclerophoma pithyophylla	24°C	0·5	—

timber in a wooden building after more than thirty years' service at Deception Island in Antarctica, and decay of packing timbers in a gas purifier tower.

ENTOMOLOGY

AMBROSIA (PINHOLE BORER) AND LYMEXYLID BEETLES

West African investigations. The deputy officer-in-charge of the West African Timber Borer Research Unit has visited the Laboratory to discuss factors governing wood-boring insect attack in standing trees with special reference to *Trachyostus ghanaensis* in wawa. Serious degrade may be caused to timbers in this way and an account of such damage in *Baikiaea* has been published[34].

Damage in coniferous forests, Argyllshire. In conjunction with the Forest Research Station, Alice Holt Lodge, new experiments were set up in the light of the results obtain last year and examinations have been carried out at intervals through the summer. Investigations were concentrated at Glen Duror Forest which, in 1959, had proved to be the most suitable area for these studies. The monthly felling series of full length Sitka spruce stems initiated in November 1958 has been continued on a reduced scale but since only negligible attack had been found in barked timber, these fresh stems have not been barked. Only one of these unbarked stems felled in November 1959 was attacked this summer. This may be of significance as the three most heavily attacked stems in the 1958–59 series were also November fellings. Examination of the 1958–59 original series of stems felled at Glen Duror, Glenfinart and Glenbranter revealed that no fresh attack had occurred in them during this year.

A fresh experiment was set up at Glen Duror to obtain information on the relationship between time of felling and the relative susceptibility of tree species to attack by *Trypodendron lineatum.* Billets 5 ft long of Douglas fir, European spruce, Japanese larch and Sitka spruce were arranged on the ground at 2-ft intervals in a Graeco-Latin square. Heavy attack was present in one of European spruce and one of Japanese larch stems. Other portions from the same logs placed in the forest at considerable distances were also heavily attacked, thus indicating that individual trees may be particularly susceptible to attack.

The effect of insecticides in preventing attack was also investigated by means of a randomized block of 5 ft long billets of Sitka spruce felled in December 1959 and sprayed in March. Examination in September revealed considerable variation in the extent of attack, but it appears 0·75 per cent gamma BHC gave the best protection. Full analysis of this result is not yet available.

Biological observations have been continued. Attack by *Trypodendron* commenced in the first part of May (a little later than last year) and continued at least into August. Small stainless steel wire mesh cages fitted with corks were designed to trap beetles emerging from infested logs. From the data obtained it appears that young beetles emerge between the latter part of July and September, thus indicating a life-cycle of about 10 or more weeks. Live *Hylecoetus dermestoides* beetles were found in May but boring by young larvae into logs was not sufficiently advanced to be detectable until the beginning of July. However, after that it continued till the final examination in mid-September. A high proportion of logs and stumps in which *Trypodendron* attack was noted early in the summer were subsequently found to be attacked by *Hylecoetus*, indicating that certain logs and stumps are attractive to both insects.

A mercury vapour lamp light trap, made to the design of the Rothamsted Experimental Station, was operated in a wind blown area in the forest to ascertain whether this method of trapping could be used for further biological studies of *Trypodendron* and *Hylecoetus*. Neither of these species, however, proved sensitive to such a stimulus, but other insects of forest importance were obtained. After examination of these at the Forest Research Station, the remainder (chiefly Diptera and Lepidoptera) will be sent to the Rothamsted Experimental Station for identification, since it is thought the catch will yield data of general entomological importance from a type of habitat not previously investigated in this way.

Lyctus POWDER-POST BEETLES

Starch depletion in kiln-dried and air-dried European oak in relation to infestation. This project has been completed and the results analyzed and prepared for publication[35]. Kiln- and air-seasoned material not showing attack after exposure to *Lyctus* in 1957 and 1958 was re-exposed in 1959 under conditions favouring accelerated larval development and the results incorporated with the data previously obtained. Kiln seasoning of 1 in. European oak boards produced greater starch depletion resulting in less *Lyctus* attack than air seasoning. Practically all the starch depletion in the kiln seasoned material took place during the intial stages of the schedule when the temperature was 40·5°C and the relative humidity 80 to 85 per cent. Previous work on green English ash discs by Henderson [36] was repeated using European oak in a saturated atmosphere. The optimum temperatures for rapid starch depletion were 40°C to 43·5°C, but at 45°C the cells were presumably killed and no depletion occurred. These results indicate that far from kiln seasoning increasing the susceptibility of this timber to *Lyctus* attack the reverse is the case. It seems probable that in general, timbers seasoned at mild kiln schedules starting at 40°C or less and at high relative humidities would show greater starch depletion and less susceptibility to *Lyctus* than by air seasoning, whereas the reverse might be true for fast kiln schedules starting at or above 45°C.

Prevention of infestation in sawn logs. The data previously obtained from exposure of beetles to dip treated timber (see the Annual Report 1959 p. 34) have now been analyzed and the results published[37] and included in a revised edition of Forest Products Research Leaflet No. 43.

Culturing under controlled conditions. A standard technique of rearing all stages of *Lyctus brunneus* throughout the year has been employed at this Laboratory since 1945. A number of requests for details of the method have been received and a full description has been published[38].

HOUSE LONGHORN BEETLE (*Hylotrupes bajulus*)

Occurrences. Although infestations have been reported from post-war houses fewer fresh instances of attack have been detected and no new areas have been involved.

Biological Studies. During visits to laboratories on the Continent, data on their methods of culturing this insect were obtained. Formerly the initiation of experiments at the Laboratory has always been limited to the normal summer emergence of adults, which has varied with weather conditions. As a first step towards obtaining a more regular supply of beetles to start cultures, a large number of larvae have been inoculated into 3-ft lengths of suitable timber for storage in the new insectary. Experiments are continuing on conditions which might reduce the length of the life-cycle, i.e. temperature, humidity and the addition of nutritive substances to wood. The results of experiments started in 1958 (see the Annual Report 1958 p. 34) with Scots pine blocks impregnated with 6 per cent of their dry weight of peptone showed an accelerated larval growth and a shorter, though still unpredictable, life-cycle, but some emergence was obtained after one year. This investigation has been expanded and 6 in. lengths of Scots pine sapwood have been impregnated under pressure with aqueous solutions of 0·01 per cent aureomycin, 0·5 per cent peptone and 1 per cent ammonium nitrate.

Some data on the effect of varying climatic conditions have been obtained. Newly hatched larvae were inserted in 1959 into matched blocks of fresh Scots pine sapwood stored under the following conditions:

(1) Fluctuating—temperature varying daily from 28°C at noon to 15°C at night with normal humidity.
(2) Wet tropical—daily temperature variation from 25°C to 29°C and 75 to 85 per cent relative humidity.
(3) Dry tropical—daily temperature variation from 27°C to 40°C and 20 to 42 per cent relative humidity.
(4) Constant—incubator maintained at 28°C and 85 per cent relative humidity.
(5) Roof space containing a few pipes in a central heating circuit.

Emergence after about 12 months has so far only occurred in the case of (4) above.

COMMON FURNITURE BEETLE (*Anobium punctatum*)

Work has been suspended for most of the year but some further information on the effect of soft rot on the susceptibility of beech to attack when involving losses in weight of from 14 to 19 per cent has been obtained. The results in general are similar to data previously recorded when blocks were less heavily decayed (see the Annual Report for 1959, p. 35). The larvae gained weight more rapidly in the presence of soft rot but this effect was only markedly apparent in the middle and inner zones of beech. In this instance, however, the material was not cut up until after storage at 22°C and 85 per cent relative humidity for 25/26 months following exposure for egg-laying whereas previous experimental blocks have been cut up after a shorter interval.

DEATH-WATCH BEETLE (*Xestobium rufovillosum*)

Biological studies. Since this insect normally has a long life-cycle, an experiment has been started to investigate the possibility of speeding up the rate of

development by finding suitable culture conditions and so facilitating experimental work. Decayed European oak sapwood has been exposed to newly emerged mated adults at conditions of 25°C and 75 per cent relative humidity. The results showed that some stages of the life-cycle can be shortened without seriously affecting the number of eggs laid or their viability. Further information is, however, required, for example as to whether the long period of hibernation of the sexually immature adults between pupation and emergence (August to March) is shortened or eliminated.

Field observations

(a) *Westminster Hall.* Daily collections of death-watch beetles have again been made available to the Laboratory through the co-operation of the Chief Architect, Ministry of Works (Ancient Monuments Division). Analyses of the number of beetles falling from the roofing timbers during the past two emergence seasons indicate that early collections consist almost entirely of males, females increase in numbers towards the middle of the period (about the end of April) and rise to a peak about mid-May when very few males are found. The significance of this pattern is difficult to explain since it is not known why adults fall from roofing timbers when apparently still active. Females thus collected are still capable of laying appreciable numbers of eggs.

(b) *H.M.S. Victory.* 45 death-watch beetles were collected this summer and 15 of the predatory beetle *Corynetes coeruleus.*

(c) *Round Tower, Windsor Castle.* Woodwork infested by the death-watch beetle was fumigated with methyl bromide in April 1959, and periodically examined during this year's emergence season by staff of the Ministry of Works, and by an officer of the Laboratory. No evidence of *Xestobium* could be detected but further annual inspections will be necessary before the full value of the treatment can be assessed. In contrast there was appreciable emergence of the predacious beetle, *Corynetes coeruleus*, previously known to be present, indicating that as in the case of H.M.S. Victory, this beneficial insect is more resistant to this fumigant than the death-watch beetle (see the 1959 Annual Report p. 37).

PARASITES

A technique for rearing *Theocolax formiciformis*, an ectoparasite of *Anobium punctatum*, has been developed. Life history studies have been made and the data given in Table 5 were obtained on the rates of development under different conditions (see also the Annual Report for 1959 p. 36).

Table 5

Biological data on Theocolax formiciformis

Conditions	Incubation period of eggs	Length of life-cycle
Out-of-doors	7 to 14 days	10 to 12 weeks
22°C and 75 per cent relative humidity	4 days	6 to 7 weeks
25°C and 75 per cent relative humidity	2 days	5 to 6 weeks

Although development was most rapid at 25°C, this temperature is too high for survival of *Anobium* larvae which, in consequence, had to be replaced frequently. The most suitable conditions for both parasite and host have been found to be 22°C and 75 per cent relative humidity and a culture has been set up under these conditions to facilitate further biological investigations. Of 228 progeny reared under laboratory and controlled conditions from 50 wingless females collected from naturally infested plywood stored out-of-doors, only one female and two males of the winged form were obtained. The sex ratio of the total progeny was approximately one male to five females.

PREDATORS

Studies have been initiated on two Clerid beetles, *Corynetes coeruleus* and *Paratillus carus*. Cultures of the former, a common predator of the death-watch beetle, have been set up out-of-doors and under controlled conditions of temperature and humidity for observations on the life-cycle and mode of attack.

Studies on *Paratillus carus*, a predator of powder-post beetles, have shown that a large range of sizes of larvae occur at various times of the year and a few adults overwinter within the wood and emerge in May shortly before *Lyctus* beetles. Eggs are laid within wood in the manner of *Lyctus*, whose eggs they resemble except for the absence of a strand (see Plate 8). No eggs have been found in the same vessels as *Lyctus* eggs when timber was exposed to both insects but the newly hatched larvae of *Paratillus* move easily along the wood vessels. The maximum number of eggs laid by a female during these investigations was 22.

TOXICITY OF METHYL BROMIDE TO WOOD-BORING INSECTS

Death-watch beetle. Data on the concentration/time product dosage required to arrest development of pupae have been investigated. Preliminary examination indicates that a dosage between 100 and 150 milligram hours per litre (mg h/l) is effective for both sexes.

Common furniture beetle. Further examination of infested meter boards fumigated in 1957, 1958 and 1959 at dosages from 50 to 200 mg h/l confirms that the only dosage which can be relied upon to prevent adult emergence by killing or arresting the development of larvae and pupae within the wood is a concentration/time product of 200 mg h/l. Extremely reduced emergence was obtained at 150 mg h/l.

LABORATORY TESTS OF WOOD PRESERVATIVES AND INSECTICIDES

A report on methods of test which have been found suitable at this Laboratory has been submitted to the British Standards Institution, together with comparative data on methods employed at other laboratories, since the development of British Testing Standards is now under consideration.

GAMMA RADIATION TREATMENTS

A few death-watch beetles emerged from decayed European oak sapwood blocks into which larvae of varying weights had previously been inserted and then irradiated in 1958 at 4000 roentgens (r). Although eggs were laid by these beetles, very few hatched. No beetles emerged from corresponding blocks irradiated at 6000 r or 8000 r. Beetles emerged from the untreated control blocks and laid eggs which hatched normally. No further emergence has occurred from

naturally infested willow irradiated in 1958 at 10 000 r. Only 3 beetles which were derived from larvae at the time of treatment emerged in 1959 and these were shown to be sterile. Beetles emerged from the untreated control willow and laid eggs which hatched normally. This experiment was repeated in January 1960 when immature beetles would have been present, by irradiating fresh supplies of naturally infested willow at dosages of 10 000 r or 12 000 r. Emergence took place in April from both the treated and untreated control material but although a normal number of eggs was obtained, none laid by the treated beetles hatched.

Data have been obtained by the Technological Irradiation Group of the Isotope Division, Atomic Energy Research Establishment, Wantage, on the attenuation of gamma rays in a range of thicknesses of Scots pine. A sectional block was constructed at the Laboratory for this purpose (see the 1958 Annual Report p. 39). The results showed that the attenuation of the order of 50 per cent occurred in approximately 40 cm thickness of this block.

STERILIZATION OF INSECT-INFESTED WOOD BY INFRA RED HEATING

Investigations have continued on the temperature/time relationship in the heat sterilization of *Lyctus*-infested $\frac{1}{2}$ in. thick parquet floor strips of European oak sapwood. A small number of adults subsequently emerged from this material which contained larvae, pupae and adults at the time of treatment, even after temperatures exceeding 80°C had been applied for periods up to 25 minutes. Such resistance to high temperature has not been detected in the case of the common furniture beetle (see the Annual Report for 1957, p. 39).

GENERAL

Amongst the more interesting enquiries received were two further instances of attack by the sawfly *Ametastegia glabrata* (see the Annual Report 1959, p. 39) in western red cedar and a further case of infestation by the Buprestid beetle, *Eurythyrea austriaca* (see the Annual Report 1953, p. 39).

CHEMISTRY

WOOD ANALYSIS

Variation in Composition of Wood within the Tree

The programme of investigations on home-grown timbers, undertaken jointly with the Forestry Commission, includes a study of the variation in chemical composition of wood within the stem of the tree. Three trees of Sitka spruce from Ratagan Forest, Inverness-shire, were provided for these investigations. Sample discs were cut at three heights from each tree and were separated into zones of five growth rings each, and representative portions of these were prepared for analysis.

The following determinations were carried out by the standard methods of wood analysis: Cross and Bevan cellulose, α-cellulose (on Cross and Bevan cellulose), lignin, pentosan, alcohol-benzene solubility, 1 per cent caustic soda solubility, and nitrogen content. The nitrogen content was determined after destruction of the wood substance by the method previously developed (see Annual Report for 1956, p. 46) involving digestion with concentrated sulphuric acid and hydrogen peroxide. In Figs. 6–9 the average values of cellulose content, lignin content, etc., for corresponding zones of the three trees, expressed as percentages of the dry, extractive-free weight of wood, are plotted

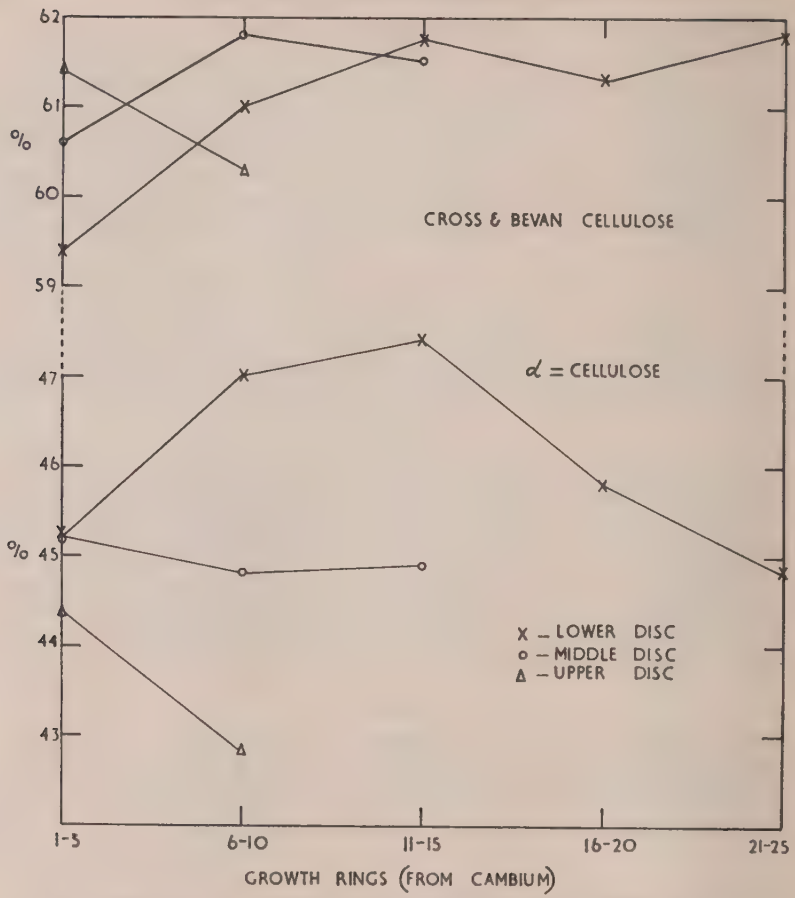


Fig. 6. Variation in cellulose content across the stem of Sitka spruce.

against the position in the stem as indicated by the growth ring numbers, which are counted from bark to pith.

Although a full statistical examination of the data has not yet been undertaken it is clear from inspection of the graphs that there is no systematic trend in the Cross and Bevan cellulose or the α-cellulose content of the wood across the stem, but that there is a fairly regular decrease in lignin content from the outer rings to the centre and from the base of the tree to the top. More extensive investigations would be necessary to confirm these trends, particularly as other workers have found the juvenile wood at the centre of the stem to have a lower cellulose content that the mature wood. It is possible that the irregularities found in the present work may be related to the presence of considerable areas of compression wood in the trees examined, because it is known that compression wood differs appreciably in composition from normal wood.

WOOD EXTRACTIVES

Indian rosewood. The investigation of the crystalline phenolic substance isolated from this timber is being continued in collaboration with University

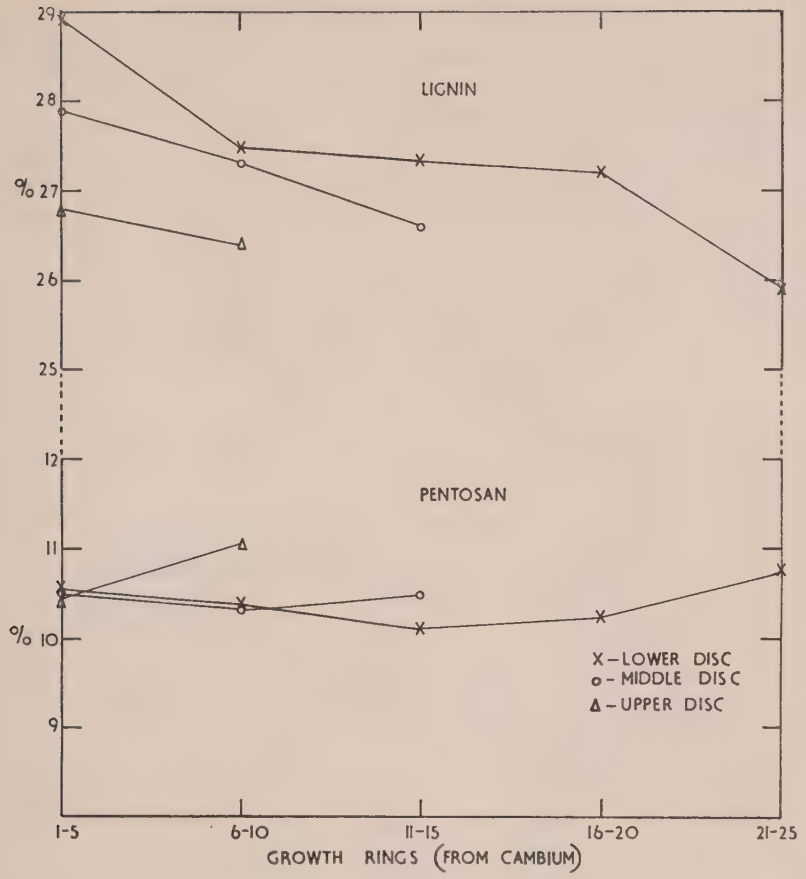


Fig. 7. Variation in lignin and pentosan content of Sitka spruce across the stem.

College, Dublin (see Annual Report for 1959, p. 39). A further batch of this product was extracted and purified, and larger-scale oxidation experiments are being carried out.

Lodgepole pine. As a preliminary to the investigation of the polysaccharides of lodgepole pine (see below), the wood was exhaustively extracted with a 1:2 alcohol-benzene mixture. When this solution was concentrated *in vacuo*, a white solid separated. This was removed and recrystallized from ethanol to yield D-mannitol, identified by its melting-point, mixed m.p., rotation, analysis, and by the formation of the crystalline hexa-acetate. From the ether-soluble portion of the extract was obtained dihydrokaempferol, identified by melting-point and mixed m.p., chromatographic behaviour and colour reactions. No appreciable amounts of any other dihydroflavanol could be detected. Pinobanksin, which had previously been found in the heartwood of this timber, was absent from the young wood investigated here.

Pyinkado. During the preparation of thin sections of this oily timber for examination of moisture content curves (see p. 41) it was observed that the

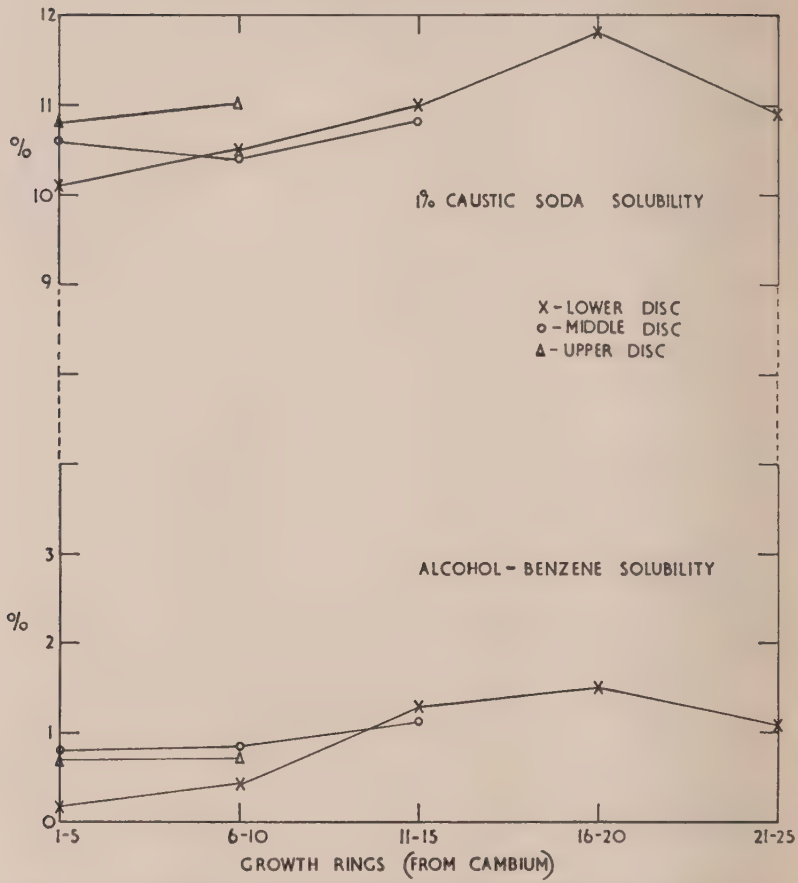


Fig. 8. Variation in 1 per cent caustic soda solubility and alcohol-benzene solubility of Sitka spruce across the stem.

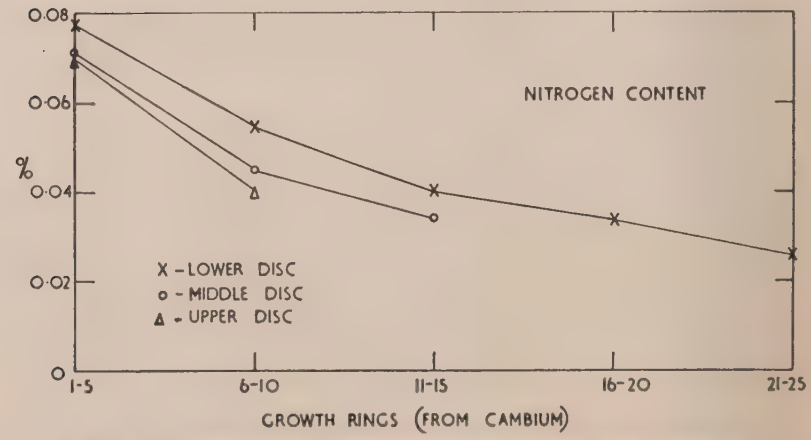


Fig. 9. Nitrogen content variation across the stem in Sitka spruce.

surface of the wood became coated with a layer of needle-shaped crystals. Separation of some of this material, by hand, was accomplished under the microscope. The product was shown to be soluble in all the common organic solvents and insoluble in water. It had m.p. *ca.* 120°C (Kofler block).

In an attempt to separate this material in quantity, the heartwood was extracted with light petroleum (b.p. 60–80°C) to give an unusually high yield of extract (*ca.* 7·5 per cent). This oily material partially crystallized, and was purified by distillation in a high vacuum. Fractionation on a column of alumina then yielded four crystalline components, with m.p.'s 26·5°C, 54–54·5°C, 99–99·5°C and 128°C. Preliminary investigations of the last three substances, including infra-red studies, analyses and the formation of derivatives, suggest that they are new compounds which may be diterpenoid in nature, though no detailed structural formulae can be proposed as yet.

WOOD POLYSACCHARIDES

Hemicelluloses in beech. Work on this subject (see Annual Report for 1959, pp. 39–40) has been concluded, and a paper has been submitted for publication[39].

Polysaccharides of lodgepole pine. An investigation to evaluate the pulping properties of home-grown lodgepole pine is in progress (see below), and, concurrently, a study of its polysaccharides has been undertaken. Treatment of extractive-free wood with cold water removed a mixture of polysaccharides which gave, on acid hydrolysis, arabinose, galactose, glucose, mannose, xylose and a trace of rhamnose. Fractional precipitation of the purified product from aqueous solution with ethanol effected removal of the glucomannan component. Attempts to reduce the residual xylan content (*ca.* 2 per cent) by precipitation as the copper complex with Fehling's solution were unsuccessful. The product, at this stage, yielded on hydrolysis galactose (7 parts) and arabinose (1 part) along with small amounts of xylose and traces of rhamnose. Attempts at further fractionation are being carried out.

These preliminary experiments have indicated that the arabogalactan is probably similar to those isolated from other coniferous timbers.

PULP AND PAPER RESEARCH

Accommodation and equipment. Work has continued on the necessary modifications to the building that is to form the pulping laboratory, and the installation of benches, drains, ventilation, etc. was completed during the year. Most of the apparatus and equipment required for pulp evaluation work has been acquired. Items obtained during the year include a pulp screen, and a set of stainless steel bombs and thermostatically controlled air bath for heating them, for carrying out small scale pulping experiments. For experiments on a larger scale, a 5-gallon jacketted digester, which can be used either as a rotary digester or as a stationary digester with liquor circulation, has been ordered. Although the pulping laboratory was not ready for occupation it has been possible to carry out a programme of pulp evaluation studies during the year in temporary accommodation.

Sitka spruce. A programme of pulping trials on home-grown Sitka spruce from various Forestry Commission plantations had been commenced at the Tropical Products Institute. These trials were designed to show what variations may be expected in the pulping properties of Sitka spruce grown on different

sites in Great Britain. Work carried out at the Laboratory on some of the same samples has served as a useful basis for calibration of the apparatus and techniques necessary for this type of investigation. It has also emphasised the difficulty in obtaining exactly parallel results from pulp evaluation trials carried out at two different laboratories.

Lodgepole pine. An investigation designed to compare the pulping and papermaking characteristics of home-grown lodgepole pine of nine different provenances has been completed. Billets were cut, at a proportional height of each tree, from ten selected trees representative of each provenance and were converted into pulping chips. Samples of the mixed chips of each provenance were pulped by the sulphate process in a laboratory-scale rotary digester. The liquor composition and cooking temperature were kept constant throughout the series but samples from each provenance were cooked for various periods of time in order to obtain pulps covering a range of degrees of delignification, as represented by their permanganate numbers (Kappa numbers). Paper sheets were prepared from the various pulps, in the unbeaten and beaten state, by the standard procedures laid down in the Second Report of the Pulp Evaluation Committee of the Paper Makers' Association, and their bursting strength, tensile strength, folding endurance and tear resistance were measured.

Some differences were found between samples of different provenance in their resistance to cooking under the conditions employed. However, when the samples were cooked to the same degree of delignification there were no major differences in paper quality. This appears to indicate that such differences in pulping properties as exist may be largely overcome by adjustment of the cooking conditions. When cooked to a Kappa number of 30–35, lightly beaten unbleached pulps from all the samples produced test sheets having good strength properties, in yields of 45–48 per cent of the dry weight of the original wood.

GENERAL

There has been some concern about the possibility of corrosion of aluminium by wood that has been treated with copper-containing preservatives, particularly in connection with the carriage of preservative-treated wood (e.g. ammunition boxes, cable drums) in aircraft. Although it is known that aluminium is sensitive towards copper compounds there is insufficient evidence at present to show whether any increase in rate of corrosion that may arise in this way is of sufficient magnitude to constitute a serious hazard.

A paper describing investigations carried out over the past few years on the development of volatile acidic substances in wood under appropriate conditions of storage has been prepared for publication[40].

PHYSICS

THE DIFFUSION OF WATER VAPOUR IN WOOD

Recent work at the Laboratory (see the 1958 Annual Report pp. 45–47) and elsewhere [41,42] has shown that the process of dynamic sorption of water vapour by wood is more complicated than was suspected, and further measurements and analysis of results have been made here during the year. The process is usually discussed in terms of Fick's law of diffusion, which has also formed the basis of many theoretical studies of drying.

The law assumes that the flow of vapour F is related to the concentration gradient $\partial C/\partial x$ by the relationship

$$F = - D\partial C/\partial x,$$

where F is measured in gm/cm² sec, C is the moisture content expressed in gm/cc and D is the diffusion coefficient (cm²/sec).

When applied to the uptake of water vapour by a plane sheet of material between one equilibrium humidity and another, Fick's law leads to the equations

$$\gamma = \frac{4}{l}\sqrt{\frac{Dt}{\pi}} \qquad \ldots\ldots\ldots\ldots(1)$$

in the early stages of the process, and

$$1 - \gamma = \frac{8}{\pi^2}\exp\left(\frac{-\pi^2 Dt}{l^2}\right) \qquad \ldots\ldots\ldots\ldots(2)$$

in the later stages, where l is the thickness of the specimen, and γ is the ratio of the increment in average moisture content at time t to the increment in moisture content when the new equilibrium is established. Results obtained at the Laboratory on wood show that equation (1) is followed closely but that equation (2) is not obeyed. In the early stages of the process it is therefore possible to obtain a diffusion coefficient from the results. Since, however, the diffusion coefficient varies with moisture content and the experiments have to be carried out over finite moisture content steps, the diffusion coefficients obtained in this way are average values over the respective moisture content ranges. Crank[43] has described a method of deriving the relationship between the true diffusion coefficient and moisture content from experiments involving finite moisture content steps, and by applying this method, the curves of Fig. 10 are obtained.

Owing to the accumulation of errors in measurement and in the graphical differentiation which forms one stage in the process of obtaining the coefficients, the accuracy of the curves is low. It is, however, sufficient to establish the existence of a difference between adsorption and desorption coefficients at the higher moisture contents, and of a maximum in both curves.

The difference between the adsorption and desorption curves does not seem to have been observed before. The shape of the diffusion coefficient-moisture content curve has been investigated previously[44] but some workers have obtained curves showing a continuous rise, others a continuous fall, and still others a maximum. Although maxima are obtained in the present tests, it appears that they are not always observed and further work is required before a complete explanation of the diffusion coefficient-moisture content relationship is available.

MOISTURE RELATIONS

Using the vacuum sorption apparatus, equilibrium moisture content curves in adsorption and desorption have been obtained for pyinkado, greenheart and albizia, in addition to the twelve timbers dealt with in the investigation described in the Annual Report for 1959 (pp. 42–44). All of the timbers were chosen because their equilibrium moisture content at 90 per cent relative humidity is low in comparison with Sitka spruce. The curves show that this difference does not always persist at low realtive humidities, and in fact a few of the timbers have higher equilibrium moisture contents than Sitka spruce at the lower humidities. The vacuum sorption experiments give data up to about

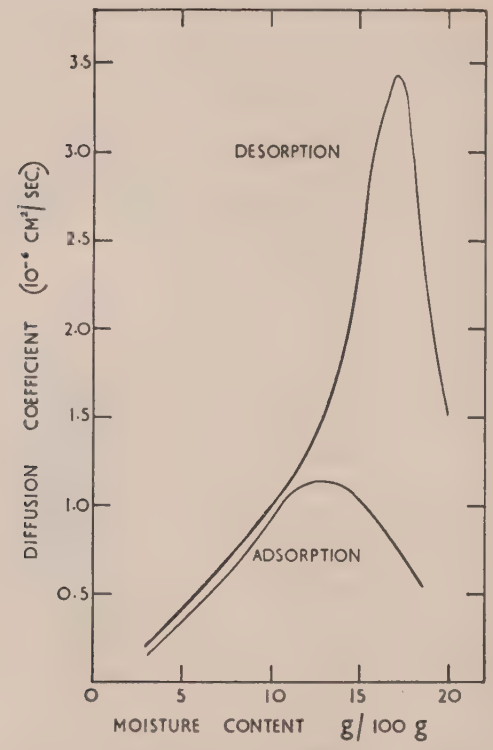


Fig. 10. Variation of initial diffusion co-efficient with moisture content.

99 per cent relative humidity and trials of other methods for obtaining data at higher humidities have been made.

A pressure membrane apparatus designed for studying the equilibrium moisture content of soils at relative humidities above about 99·9 per cent has been used in experiments with wood. Three major difficulties were encountered: (1) poor contact between the wood and the membrane; (2) passage of air through the membrane and its accumulation on the low pressure side; (3) the long time, fourteen days or more, required to reach equilibrium. These difficulties appear to be inherent either in the wood itself or in the apparatus, and work with the apparatus has now been discontinued.

EFFECT OF SPECIMEN SIZE ON SWELLING

Vorreiter[45] showed that the maximum radial and tangential swelling of Sitka spruce specimens at 20°C increased by about 50 and 80 per cent respectively when the specimen dimensions were decreased from 5 cm to 1 cm in the direction of measurement. On the other hand, Greenhill[46] found a slight decrease in shrinkage as the specimen dimensions were reduced from 1 in. to $\frac{1}{2}$ in. In view of these discrepancies, some measurements have been made on flat sawn and quarter sawn European beech specimens of transverse dimensions shown in Table 6. The swelling was measured in the direction of the major transverse dimension. The main entries in the table are the percentage swellings

Table 6

Swelling of specimens of different sizes

Nominal Cross Section in.	Swelling per cent			
	0–90 Relative Humidity		0-Saturation	
	Radial	Tangential	Radial	Tangential
$5\frac{1}{2} \times \frac{1}{2}$	4·3	6·4	5·5	10·3
$5\frac{1}{2} \times \frac{1}{4}$	4·8	7·3	5·7	10·5
$4 \times \frac{1}{2}$	4·3	7·0	5·8	11·2
$4 \times \frac{1}{4}$	4·6	8·1	5·8	12·2
$2 \times \frac{1}{2}$	4·1	7·6	5·7	12·8
$2 \times \frac{1}{4}$	4·3	7·8	5·9	11·1
$1 \times \frac{1}{2}$	4·2	7·4	5·6	12·4
$1 \times \frac{1}{4}$	4·7	9·2	6·0	14·1

between dryness and 90 per cent relative humidity (21 per cent moisture content) and between dryness and complete saturation (ca. 150 per cent moisture content).

There is a tendency for the swelling to be larger when measured on smaller specimens, especially in the tangential direction. The effect is, however, much smaller than that observed by Vorreiter, and if the results for the two extreme sizes ($5\frac{1}{2}$ in. $\times \frac{1}{2}$ in. and 1 in. $\times \frac{1}{4}$ in.) are excluded, there is little evidence of systematic change in swelling with specimen size among the remaining results.

CORRELATIONS BETWEEN VIBRATION CHARACTERISTICS OF WOOD

The frequency of vibration of a given specimen of wood is determined by an elastic constant and the density and dimensions of the specimen. The elastic constant involved depends on the type of vibration, for example in longitudinal and bending vibration, it is the Young's modulus E. Another vibration characteristic is the logarithmic decrement δ, which determines the rate at which free vibrations die away. A third characteristic is the velocity of sound C which may either be measured directly or derived indirectly from the relation $C = K/\rho$, where K is an elastic constant and ρ is the density.

In the case of an extended rod in longitudinal vibration, the constant K is the Young's modulus.

In view of the attention now being paid to the non-destructive testing of wood, it is of interest to examine the extent to which the above quantities are mutually associated. The amount of available data is limited, but a statistical analysis has been made to determine the correlation coefficients between the various vibration characteristics as estimated from

(A) 10 Douglas fir specimens of American origin[47].

(B) 28 Japanese timbers[48].

(C) 70 timbers, mainly of Italian origin[49].

The correlation coefficients are given in Table 7.

In group A the only significant correlation is that between C and E. Some of the other coefficients in this group are fairly high, but are not significant owing to the small number of comparisons available. In groups B and C, and in the group formed by combining B and C, most of the correlations are

Table 7

Correlation coefficients of vibration characteristics

Source of Date	No. of Specimens	Correlation					
		C–E	C–ρ	C–δ	E–ρ	E–δ	ρ–δ
(A)	10	0·914***	−0·198	−0·600	0·216	−0·614	−0·069
(B)	28	0·426*	−0·393*	−0·567**	0·651***	−0·023	0·420*
(C)	70	0·517***	−0·376**	−0·617***	0·580***	−0·656***	−0·093
(B) and (C) Combined	98	0·418***	−0·403***	−0·612***	0·643***	−0·353***	0·174

* = Significant at $p = 0{\cdot}05$
** = ,, ,, $p = 0{\cdot}01$
*** = ,, ,, $p = 0{\cdot}001$

significant at the 5 per cent level or better. The largest coefficients, however, do not exceed about 0·65, so that even in the most favourable case, any values predicted from the regression equation between the variables would be subject to considerable uncertainty.

DENSITY MEASUREMENT BY BETA-RAY ABSORPTION

As mentioned in the wood structure report (p. 6) further work has been done on developing a method to find the variation in density of wood across the growth rings by measuring the attenuation of a beam of beta particles on passing through the wood. Previous work[12] had shown that the method was feasible and an apparatus had been devised for measuring the density of increment cores 8 mm thick in steps of 0·5 mm. With specimens of this thickness considerable scattering takes place which has the effect of blurring sharp changes in density. This effect is also produced in thick samples if the growth rings are not perpendicular to the surface of the core.

For these reasons it was decided to use thin specimens of wood and a thickness of 100 microns was found to be most suitable. The apparatus was further improved by using an automatic feed to move the specimen slowly through the beam and by incorporating a chart recorder to obtain a continuous trace of the density variation.

Beta particles emitted by carbon-14 are of suitable penetrating power for this thickness of specimen, and a collimated beam 1·6 mm × 0·3 mm is obtained from a special high-activity carbon-14 preparation. The transmitted beta-particles are detected by a scintillation counter consisting of an anthracene crystal and a photomultiplier. The output pulses from the photomultiplier are fed after amplification to a logarithmic ratemeter and then to a recorder (see Fig. 11). The apparatus has been designed to ensure accurate alignment of the source and detector, and experiments have been made with slits of various widths in front of the detector to find the optimum resolution consistent with a high count rate.

The development work was done at Harwell in conjunction with the D.S.I.R. Radio-Isotope Applications Unit. Equipment has now been obtained and assembled for use here.

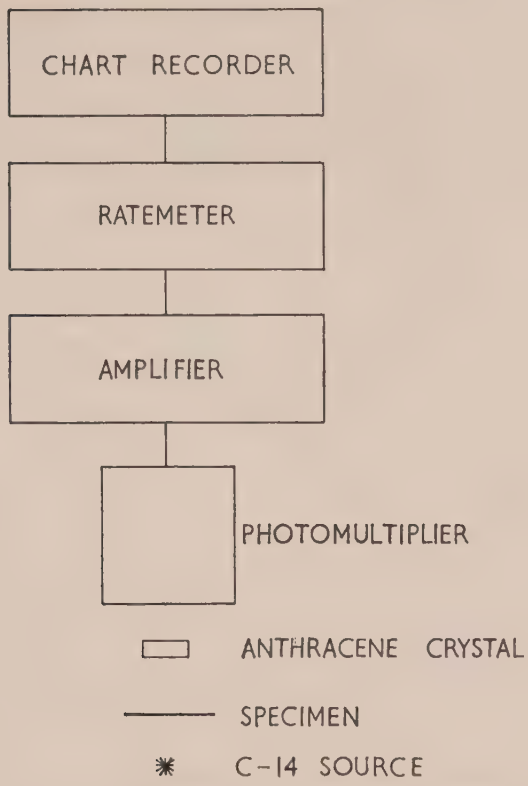


Fig. 11. Block diagram of beta-ray density equipment.

EXTERNAL RELATIONS

A total of 6031 cu. ft of round and sawn timber and 1200 home-grown pit-props were received at the Laboratory during the year. Of this quantity, there were 1977 cu. ft of imported hardwood. The home-grown timber consisted of 2658 cu. ft of softwood and 1369 cu. ft of hardwood. One of the consignments of softwood was from the Republic of Ireland.

GENERAL TESTS

Reports on the general properties of the following timbers were completed and circulated: white seraya and a species of light red seraya from North Borneo, and *Khaya grandifoliola* from Nigeria.

Investigations have been completed on a consignment of Turkey oak and a final report is being prepared.

INVESTIGATIONS ON HOME-GROWN SITKA SPRUCE

A further three consignments of Sitka spruce, from the north of Scotland, completed the eighteen consignments received for an extensive investigation of the timber properties. Each consignment consisted of ten trees and the logs were graded according to the scheme outlined in the 1959 Annual Report p. 46. Since much of the timber was allocated to the sections in the form of bolts, it

was not possible to correlate the log grading with the quality of sawn timber. Defects such as drought cracks, rot and stain were noted although they were not accounted for in the log grading system.

One consignment of three trees was received for an intensive investigation on the pattern of variation within individual trees. Rate of growth and specific gravity measurements were made on groups of five growth rings across the stem and taken at five heights in each tree. The percentage of summer wood in the growth rings of these samples was also measured. The work will be continued on receipt of the two other consignments.

GENERAL INVESTIGATIONS ON LODGEPOLE PINE

A consignment of lodgepole pine, from Blessington Forest, Republic of Ireland, was received for a general assessment of the timber properties. The trees were 28 years old, plantation-grown and from two adjacent plots. The logs were graded on the same basis as those of Sitka spruce and, as the timber was all converted into planks, it was possible to correlate the grades of logs with the grades of sawn timber obtained. This work brought to light the need for certain alterations in the log grading system and enabled an improved and simplified method to be devised for future use. Comparison of sawn material showed a marked difference in the quality of timber produced by the two plots.

An analysis was made of the rate of growth, specific gravity and percentage summer wood of ten trees, selected to cover the range of the material from each of the two plots. Each of the trees was sampled at three heights and at five-year growth intervals from the centre at each height. The timber had fast, even growth, with a rather low specific gravity for a pine. There was a noticeable difference between material from the two plots in respect to rate of growth, specific gravity and percentage heartwood, though the percentage of summer wood was similar in both cases.

The differences noted in the material from the two plots support an assumption, based on differences in tree form, that the two plots may have been planted with seed of different provenances. A report on this work has been written.

INVESTIGATIONS ON LODGEPOLE PINE FROM DIFFERENT SEED PROVENANCES

Nine consignments of lodgepole pine, grown from seed of nine different provenances, were received from the Forestry Commission. The consignments ranged in age from 23 to 30 years; seven of them were from Clocaenog Forest and two from Beddgelert. Rate of growth and specific gravity determinations were made on discs taken at $\frac{1}{8}$ and $\frac{1}{4}$ of the total height of the trees. Variation of these properties across the section of the stem at each height was ascertained and a detailed examination was made of the percentage of summer wood in the growth rings near the butt.

The sawn timber was not examined, as the wood was allocated to sections mainly in the form of bolts. The investigations on these consignments are almost completed, but the results have yet to be analysed.

EFFECT OF THINNING GRADE ON THE TIMBER OF SCOTS PINE

Work has been started on an investigation of Scots pine to determine the effect of thinning treatment of the stand on the resulting timber. Four consignments of 73 year old Scots pine have been received, all from the same site near

Bagshot, Surrey, representing four stands, thinned to Grades A, B, C and D respectively.

The consignment from the D grade plot, has been converted and allocated for various investigations. The logs were graded using the simplified log grading rules referred to above and the material was then converted into planks which were also graded. The grades of planks obtained will form a basis of comparison of the timber from the four stands. It will also enable the quality of logs to be correlated with the quality of the sawn timber they provide. Ten trees, selected to cover the girth range of the consignment, were sampled for rate of growth, specific gravity and percentage summer wood, discs being cut near the butt and at half the total height of the tree and divided into 5-year growth periods to determine the variation across the stem.

The work on this consignment is almost completed and the other three consignments will be sampled similarly.

PROPERTIES OF INDIVIDUAL GROWTH RINGS IN EUROPEAN LARCH AND JAPANESE LARCH

Work was completed and a report prepared on an investigation into the influence of variations in the percentage and density of summer wood and spring wood on the specific gravity of individual growth rings. Nine trees of European and Japanese larch were selected from three sites, and the work was limited mainly to discs from the butt.

The percentage of summer wood gave the highest correlation with specific gravity and could account for 70 per cent of its variation. The density of the summer wood gave a better correlation with specific gravity than did the density of the spring wood. The percentage of summer wood also bore a close relation to the rate of growth and ranged from 15 to 60 per cent in the material studied. The measured values of specific gravity of the summer wood and the spring wood ranged respectively around ·700 and ·300; that of the summer wood showed some relation to rate of growth, narrower rings tending to have more dense material, but the spring wood density varied mainly with age, decreasing steadily during the first fifteen years of growth to a uniform level in later years.

The only significant difference observed between the two species was that the density of the summer wood was slightly higher in the European larch. In both species the percentage of summer wood gave the same relation to rate of growth and to specific gravity. It is therefore to be expected that the characteristically faster initial growth of Japanese larch should be associated with a lower percentage of summer wood and a lower specific gravity.

GRADING OF HOME-GROWN CONIFEROUS LOGS

Work has been started on formulating rules for the grading of round conifer logs. The formulation of satisfactory rules will take some time, as they must be based on the grading of a quantity of timber.

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January, 1961

APPENDIX I

STAFF OF THE FOREST PRODUCTS RESEARCH LABORATORY

31st *December*, 1960

Director of Forest Products Research: A. C. Copisarow, D.Sc., F.Inst.P., A.M.I.E.E.
F. Y. Henderson, C.B.E., D.Sc., D.I.C., F.I.W.Sc.*

ADMINISTRATION

Assistant Director: J. Bryan, M.Eng., A.M.I.C.E.
Senior Principal Scientific Officer: P. Harris, B.Sc.(Eng.), A.M.I.Mech.E.
Higher Executive Officer: J. D. Bingham.
Executive Officer: H. T. Johnson.

SECTION OF WOOD STRUCTURE

Principal Scientific Officers: B. J. Rendle, B.Sc., A.R.C.S., F.I.W.Sc. (Officer in Charge); E. W. J. Phillips, B.Sc., Ph.D., A.R.C.S.
Senior Scientific Officer: J. D. Brazier, B.Sc.
Experimental Officers: G. L. Franklin; D. G. Patterson, M.Sc.

SECTION OF PHYSICS

Principal Scientific Officer: R. F. S. Hearmon, F.Inst.P., F.I.W.Sc. (Officer in Charge).
Experimental Officers: E. H. Adams; J. McC. Paton.

SECTION OF SEASONING

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Senior Experimental Officers: R. E. Hodge, Assoc.I.Mech.E.; D. D. Johnston; G. H. Pratt; N. Turner.
Experimental Officer: A. R. Dean.
Assistant Experimental Officer: R. H. Wynands.
Temporary Assistant Experimental Officer: D. C. Bedding.

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Senior Scientific Officers: A. J. Comben, B.Sc.; W. T. Curry.
Experimental Officers: G. R. Brock; W. T. Hide; Miss G. M. Lavers.
Assistant Experimental Officer: S. A. Covington.
Temporary Assistant Experimental Officer: Mrs. W. M. Hudson.

SECTION OF WOOD PRESERVATION

Principal Scientific Officer: D. N. R. Smith (Officer in Charge).
Temporary Scientific Officer: D. J. Danbury, M.Sc.
Experimental Officers: R. Cockcroft, A.I.W.Sc.; Miss E. Lee; D. F. Purslow, B.Sc.; L. W. Redding.

* Retired 31st October, 1960.

SECTION OF CHEMISTRY

Principal Scientific Officer: R. H. Farmer, B.A., B.Sc., D.Sc.(Tech.), F.R.I.C. (Officer in Charge).
Senior Scientific Officers: R. A. Laidlaw, B.Sc., Ph.D.; J. W. W. Morgan, B.Sc., Ph.D., A.R.I.C.
Senior Experimental Officer: D. F. Packman, B.E.M.
Experimental Officers: J. A. H. Broughton, B.Sc., A.I.W.Sc.; L. C. Pinion, B.Sc.
Assistant Experimental Officers: R. J. Orsler; G. A. Smith.

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Experimental Officer: E. C. Badcock.

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Principal Scientific Officer: J. D. Bletchly, T.D., B.A., B.Sc., F.R.E.S., M.Inst.Biol., F.I.W.Sc. (Officer in Charge).
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Experimental Officer: Miss J. M. Taylor, B.Sc., M.Inst.Biol.

SECTION OF WOODWORKING

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Senior Experimental Officers: H. J. Endersby; R. Goodchild.
Assistant Experimental Officer: J. W. Rogers.

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Principal Scientific Officer: F. G. O. Pearson, B.Sc. (Officer in Charge).
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Experimental Officer: Miss C. Webster.

SECTION OF COMPOSITE WOOD

Principal Scientific Officer: R. A. G. Knight, B.Sc.(Eng), M.I.Mech.E., F.I.W.Sc. (Officer in Charge).
Senior Scientific Officer: J. F. S. Carruthers, B.Sc., A.M.I.Mech.E.
Senior Experimental Officers: L. S. Doman; R. J. Newall.
Experimental Officer: R. W. Hudson.
Assistant Experimental Officer: B. H. Paxton, B.Sc., Grad.Inst.P.

SECTION OF PUBLICATIONS AND RECORDS

Senior Experimental Officers: C. J. N. McCracken, B.A., Dip.For. (Officer in Charge); A. J. Foord.
Assistant Experimental Officer: T. Harding.

DRAWING OFFICE AND PHOTOGRAPHY

Experimental Officer: E. A. Steel, Assoc.I.Mech.E.
Senior Photographer: W. J. Baldwin.

APPENDIX II

LIST OF PUBLICATIONS ISSUED DURING 1960

A. STATIONERY OFFICE PUBLICATIONS

Forest Products Research, 1959.

Bulletins:

No. 25 Identification of Hardwoods. A Lens Key. (*Second Edition.*)

No. 45 The Strength Properties of Timber. By F. H. Armstrong, M.Sc., M.I.Mech.E. (Superseding Nos. 28 and 34.)

Leaflets:

No. 6 Dry Rot in Buildings. Recognition, Prevention and Cure. (*Revised Edition.*)

No. 43 Prevention of *Lyctus* Attack in Sawn Hardwoods by Use of "Contact" Insecticides. (*Revised Edition.*)

Special Report:

No. 14 Theory of Cutting. Part 1. Experiments in Rectilinear Cutting. By K. J. S. Walker, M.A., A.M.I.Mech.E., and R. Goodchild.

B. OTHER PUBLICATIONS

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APPENDIX III

REFERENCE LIST OF COMMON NAMES CITED IN TEXT

Abura	*Mitragyna ciliata*
African mahogany	*Khaya* spp.
Afrormosia	*Afrormosia elata*
Albizia	*Albizia* spp.
Ash	*Fraxinus excelsior*
Ash, English	*Fraxinus excelsior*
Beech	*Fagus sylvatica*
Beech, European	*Fagus sylvatica*
Birch	*Betula* spp.
Californian redwood	*Sequoia sempervirens*
Caribbean pitch pine	*Pinus caribaea*
Cedar, Western red	*Thuja plicata*
Corsican pine	*Pinus nigra* var. *calabrica*
Douglas fir	*Pseudotsuga taxifolia*
English ash	*Fraxinus excelsior*
English oak	*Quercus robur* and *Q. petraea*
European beech	*Fagus sylvatica*
European larch	*Larix decidua*
European oak	*Quercus robur* and *Q. petraea*
European spruce	*Picea abies*
Fir, Douglas	*Pseudotsuga taxifolia*
Fir, noble	*Abies procera*
Gaboon	*Aucoumea klaineana*
Greenheart	*Ocotea rodiaei*
Hornbeam	*Carpinus betulus*
Indian rosewood	*Dalbergia latifolia*
Ironwood	probably *Caesalpinia granadillo*
Japanese larch	*Larix leptolepis*
Larch	*Larix* spp.
Larch, European	*Larix decidua*
Larch, Japanese	*Laris leptolepis*
Light red seraya	*Shorea waltoni*
Lodgepole pine	*Pinus contorta*
Mansonia	*Mansonia altissima*
Mushebeya	*Albizia glaberrima* var. *glaberrima*

Niangon	*Tarrietia utilis*
Nkoba	*Lovoa brownii*
Noble fir	*Abies procera*
Oak, English	*Quercus robur* and *Q. petraea*
Oak, European	*Quercus robur* and *Q. petraea*
Oak, Turkey	*Quercus cerris*
Pine, Caribbean pitch	*Pinus caribaea*
Pine, Corsican	*Pinus nigra* var. *calabrica*
Pine, Lodgepole	*Pinus contorta*
Pine, Scots	*Pinus sylvestris*
Pine, Yellow	*Pinus strobus*
Pyinkado	*Xylia dolabriformis*
Redwood	*Pinus sylvestris*
Redwood, Californian	*Sequoia sempervirens*
Rosewood, Indian	*Dalbergia latifolia*
Scots pine	*Pinus sylvestris*
Seraya, Light red	*Shorea waltoni*
Seraya, White	*Parashorea malaanonan*
Sitka spruce	*Picea sitchensis*
Spruce, European	*Picea abies*
Spruce, Sitka	*Picea sitchensis*
Turkey oak	*Quercus cerris*
Walnut	*Juglans regia*
Wawa	*Triplochiton scleroxylon*
Western red cedar	*Thuja plicata*
White seraya	*Parashorea malaanonan*
Whitewood	*Abies alba*
Willow	*Salix* spp.
Yellow pine	*Pinus strobus*

INDEX

Abura
  kiln drying, 6
Adhesives
  durability, 17
  R.F. Heating, 19
  tests, 17, 18
African mahogany
  plywood, durability of glues, 17
African satinwood
  anatomical studies, 5
Afrormosia,
  kiln drying, 6
Albizzia
  moisture relations, 41
Ash
  "Indian shape" hockey bends, 9
Association of British Plywood Manufacturers, 3
Atomic Energy Research Establishment, 35

Baikiaea sp.
  Trachyostus ghanaensis attack, 30
Beech
  Anobium attack, 32
  colour changes during drying, 29
  glued joints, durability, 17
  kiln drying, 6
  soft rot, 28
Bending, *see* Woodbending
Birch
  bark form and veneer figure, 19
  plywood, durability of glues, 17
British Standards Institution, 34
Buildings and equipment, 4
Bungalow
  experimental, design and construction, 11

Californian redwood
  soft rot, 28
Caribbean pitch pine
  penetration of preservatives, 24
Cedar, Western red, *see* Western red cedar
Check list of common names, 55–56
Chemistry
  cellulose content, 35
  corrosion of aluminium, 40
  extractives, 36
  polysaccharides, 39
  pulp and paper research, 39
Collections
  cultures, 27
  timber specimens, 5
Common furniture beetle, *see* Insects, *Anobium punctatum*
Corsican pine
  staining, 29

Death-watch beetle, *see* Insects, *Xestobium rufovillosum*
Density measurement
  beta-ray, 6, 44
D.S.I.R. Radio Isotope Applications Unit, 6, 44
Douglas fir
  bark-beetle attack, 30
  laminated, working stresses, 11
  preservative treatment, 23

Education, 3
Entomology, *see* Insects
European larch
  properties of growth rings, 47
European oak
  Lyctus attack, 31
  veneer trials, 19
  death-watch beetle studies, 32, 33
European spruce
  bark beetle attack, 30
  natural durability, sawdust method, 27

Fédération Européenne de l'Industrie du Contra-plaqué, 3
Fir, Noble, *see* Noble fir
Food and Agriculture Organisation, 16
Forest Departments
  Brunei, 5
  Northern Rhodesia, 5

Forest Research Station, Alice Holt, 30, 31
Forestry Commission, 1, 2, 5, 6, 10, 11, 12, 19, 35, 46
Fungi
Ceratocystis coerulescens, 29, 30
Ceratocystis pilifera, 30
Chaetomium globosum, 28
Coniophora cerebella, 27
Diplodia pinea, 29, 30
Fomes annosus, 29
Hormodendron resinae, 29
Humicola grisea, 28
Leptographium lundbergii, 29, 30
Polystictus versicolor, 27
Sap stain, 29, 30
Soft rot, 28
Sporocybe Sp., 29
Trichoderma viride, 28
Fungicides
toxicity of creosote, 28
toxicity of pentachlorophenate, 28
toxicity of orthophenylphenate, 28
Furniture Development Council, 1

Gaboon
plywood, durability of glues, 17
Gamma-ray treatments, *see* Insects, *Xestobium rufovillosum*, 34
Grading, 47
Greenheart
moisture relations, 41

H.M.S. *Victory*, 33
Hornbeam
bending, 9
House longhorn beetle, *see* Insects, *Hylotrupes bajulus*

Identification of timbers, 4–5
Imperial College of Science, 4
Indian rosewood
extractive toxic to fungi, 28
extractives, 36

Insects
Ambrosia (pinhole borer) beetles, 30
Trachyostus ghanaensis, 30
Trypodendron lineatum, 30, 31
Hylecoetus domestoides, 31
Ametastegia glabrata, 35
Anobium punctatum, 32
parasites, 34
softrot and attack in beech, 32
Corynetes coeruleus, 33
Insects—*contd.*
Eurythyrea austriaca, 35
Fumigation, 34
Hylotrupes bajulus, 32
biological studies, 32
Lyctus sp., 31
dip-treated timber, 31
predators, 34
starch depletion and attack, 31
sterilization by infra-red heat, 35
Lyctus brunneus
rearing technique, 31
Paratillus carus, 34
Theocolax formiciformis, 33
Xestobium rufovillosum, 32
biological studies, 32
fumigation, Round Tower, Windsor Castle, 33
gamma-ray treatments, 34
occurrence, H.M.S. *Victory*, 33
occurrence, Westminster Hall, 33
Insecticides
bark beetles, 30
laboratory tests, 34
methyl bromide, toxicity to *Xestobium*, 33, 34
methyl bromide, toxicity to *Anobium*, 34
methyl bromide, resistance of *Corynetes*, 33
International Congress of Entomology, 4
Ironwood
kiln drying, 7

Japanese larch
bark-beetle attack, 30
properties of growth rings, 47

Khaya anthotheca
anatomical studies, 5
Khaya grandifoliola
anatomical studies, 5
bending, 9
durability of tension wood, 27
general tests, 45
kiln drying, 6
woodworking, 16
Khaya ivorensis
durability of tension wood, 27

Larch
laminated, strength of curved beams, 12
laminated, working stresses, 11

Larch, Japanese, *see* Japanese larch
Light red seraya
  anatomical studies, 5
  bending, 9
  general tests, 45
  woodworking, 16
Lodgepole pine
  durability, 27
  extractives, 37
  penetration of preservatives, 24
  polysaccharides, 39
  properties, 6
  provence studies, 46
  pulp and paper research, 40
  quality studies, 46
  seasoning, 7
  strength and specific gravity, 10
  woodworking, 16
Lyctus brunneus, *see* Insects

Mahogany, African, *see* African mahogany
Mansonia
  kiln drying, 6
Ministry of Works, (Ancient Monuments Division), 33
Moisture relations, 41
Myshebeya
  anatomical studies, 5
Mycology, *see* Fungi

National Physical Laboratory, 21
Natural durability
  sawdust method, 27
  Indian rosewood extractive, 28
Niangon
  kiln drying, 6
Nkoba
  anatomical studies, 5
Noble fir
  creep in beams, 12

Paper Makers' Association, 40
Physics
  density by beta ray, 44
  moisture relations, 41
  specimen size and swelling, 42
  vibration, 43
  water vapour diffusion, 40
Pine, Yellow, *see* Yellow pine
Pitch pine, Caribbean, *see* Caribbean pitch pine
Plywood
  bending, 9
  durability of adhesives, 17
  electrical constants, 20
  glue testing, 17, 18
  veneer preparation, 19
Preservation, *see also* Fungicides, and Insecticides
  creosote movement, 23
  distribution of preservatives, 25
  penetration of preservatives, 23
  permeability, 21
Publications, 2, 53–54
Pulp and paper research, *see* Chemistry
Pyinkado
  extractives, 37
  moisture relations, 41

Redwood, Californian, *see* Californian redwood
Redwood
  laminated, strength of curved beams, 12
  penetration of preservatives, 23
Rothamsted Experimental Station, 31
Round Tower, Windsor Castle, 33

Sap stain, *see* Fungi
Satinwood, African, *see* African satinwood
Scots pine
  effect of thinning, 46
  laminated, working stresses, 11
  Lyctus attack, 32
  seasoning, 7
  soft, rot, 28
  stain preventive, 29
Seasoning
  air drying, 7
  kiln drying, 6
Seraya, Light red, *see* Light red seraya
Seraya, White, *see* White seraya
Sitka spruce
  air drying, 7
  bark beetle attack, 30
  cellulose content, 35
  extractives, 36
  laminated, strength of curved beams, 12
  laminated, working stresses, 12
  moisture content and specific gravity, 7
  moisture relations, 41
  permeability, 21

Sitka spruce—*contd.*
properties of thinnings, 5
pulp and paper research, 39
quality studies, 45
seasoning, 7
specimen size and swelling, 42
strength and specific gravity, 10
woodworking, 13
Staff, 51–52
Strength tests
creep in beams, 12
growth studies, 10
laminated, influence of curvature, 12
laminated, working stresses, 11

Technische Hochschule, Dresden, 5
Tropical Products Institute, 39
Timber Development Association, 1
Turkey oak
durability, 27
general tests, 45
seasoning, 7
veneer trials, 19
woodworking, 16

Universities:
Aberdeen, 4
Bangor, 4
Edinburgh, 4
Oxford, 4
Zagreb, 5
Zeged, 5
University College, Dublin, 36

Veneers, *see* Plywood
Visits overseas, 3, 4
Visitors to Laboratory, 4

Walnut
kiln drying, 6
Wawa
Trachyostus ghanaensis attack, 30
West African Timber Borer Research Unit, 30
Western red cedar
Buprestid beetle attack, 35
sawfly attack, 35
Westminster Hall, 33
White seraya
anatomical studies, 5
bending, 9
general tests, 45
woodworking, 16
Whitewood, 23
Woodbending
laminated bending, 9
miscellaneous tests, 9
plywood bending, 9
solid bending, 9
Woodworking
chain saws, 16
planing, 13–14
sawmilling survey, 17
sharpness of tools, 14
stresses in circular saws, 15
theory of cutting, 16
World Forestry Congress, 3, 12

Yellow pine, 6

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